

3.5 Seabirds

Seabirds spend the majority of their life at sea rather than on land. The group includes albatrosses, shearwaters, petrels (*Procellariiformes*), cormorants (*Pelecaniformes*), and two families of *Charadriiformes*, gulls (*Laridae*), and auks (*Alcidae*), such as puffins, murres, auklets, and murrelets. Several species of sea ducks (*Merganini*) also spend much of their lives in marine waters and are included in this supplemental environmental impact statement (SEIS) in Section 3.5.15. Other bird groups contain pelagic members, such as swimming shorebirds (*Phalaropodidae*), but they seldom interact with groundfish fisheries, and therefore will not be further discussed.

Thirty-eight species of seabirds breed in Alaska. More than 1,600 colonies have been documented, ranging in size from a few pairs to 3.5 million birds (Figure 3.5-1). The U.S. Fish and Wildlife Service (USFWS) is the lead federal agency for managing and conserving seabirds and is responsible for monitoring the distribution and abundance of populations. Breeding populations are estimated to contain 36 million individual birds in the Bering Sea and 12 million in the Gulf of Alaska (GOA) (Table 3.3-1); total population size (including subadults and nonbreeders) (Table 3.3-2) is estimated to be approximately 30 percent higher. Five additional species that occur in Alaskan waters during the summer months contribute another 30 million birds.

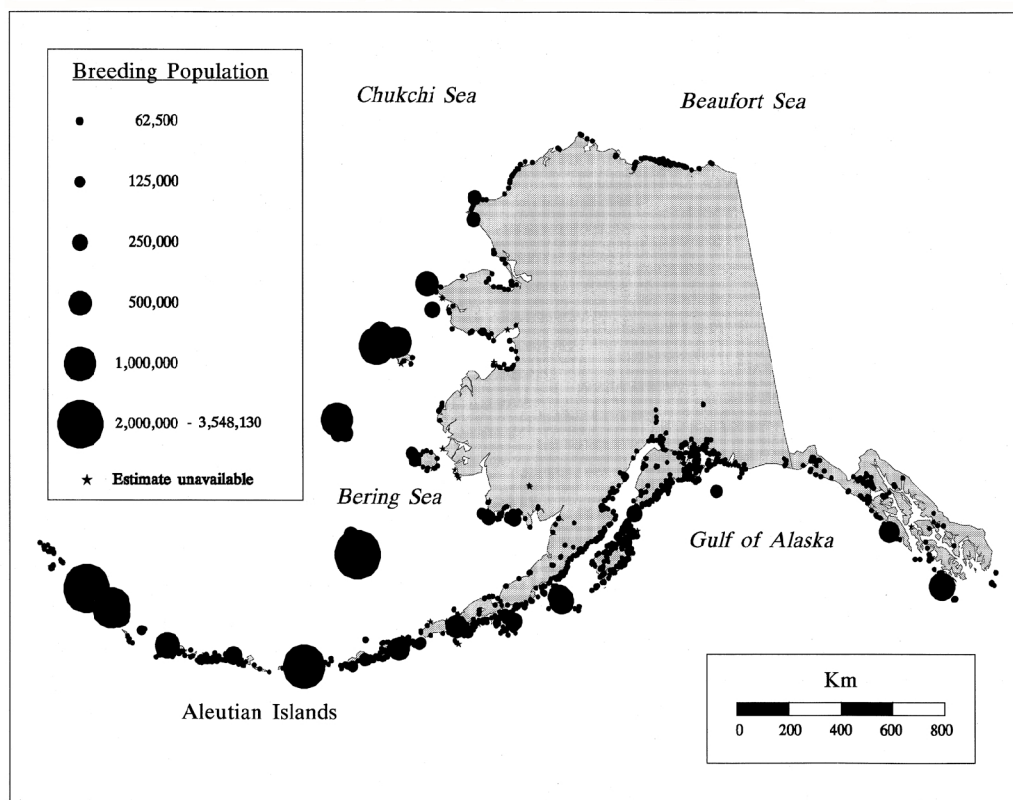


Figure 3.5-1 Seabird colonies of Alaska. Source: USFWS 2000

Population trends are monitored at 3 to 14 colonies per species. The sizes of breeding populations of seabirds in the GOA, eastern Bering Sea, and Aleutian Islands are not static. The size of breeding populations are presented with discussions of their respective species in Section 3.5.1. There have been considerable changes

in the numbers of seabirds breeding in Alaskan colonies since the original counts made in the mid-1970s. Trends are reasonably well known for species that nest on cliffs or flat ground such as fulmars, cormorants, glaucous-winged gulls, kittiwakes, and murre (Tables 3.5-1, 3.5-2, and 3.5-4), and for storm-petrels and tufted puffins. Trends are known for one or two small areas of the state for pigeon guillemots, two areas for murrelets, and two areas for auklets (Table 3.5-2 and 3.5-3). Not known are trends for other species (jaegers, terns, most auklets, and horned puffins, Byrd and Dragoo 1997, Byrd et al. 1998, 1999). Population trends differ among species. Trends in many species vary independently among areas of the state, due to differences in food webs and environmental factors.

Table 3.5-1 Population Trends of Breeding Alaskan Seabirds: Fulmars, Storm-Petrels, Cormorants, and Gulls

Location	Northern Fulmars	Storm-Petrels	Pelagic Cormorants	Red-faced Cormorants	Glaucous-winged Gulls
Chukchi Sea			?		
Northern Bering Sea			?		
Central & Southeast Bering Sea	0			?	?
Bristol Bay			0	?	?
Western Aleutian Islands		+	--	?	--
Central Aleutian Islands	?	0	?	?	0
Eastern Aleutian Islands		+	--	?	--
Western Gulf of Alaska	0	?	--	--	?
Northern Gulf of Alaska		?	--	?	+
Southeast Alaska		+	+		0

Notes: + – Increase
0 – Stable
– – Decline

? – Trend unknown
blank – Species not present

Other notes: Trends are shown for the last 5 to 20 years for species monitored for four years or more. See text for earlier trends. Each area covers about 500 km of coast and includes one or more monitoring sites. If trends vary among colonies in an area, the trend shown is for the area's overall population. No information on trends exists for double-crested cormorants, gulls (other than the glaucous-winged gull), or jaegers. Trends in albatross and shearwater populations are described in text. For sources, see text.

Seabirds are characterized by low reproductive rates, low annual mortality, long life span, and delayed sexual maturity—traits that make populations extremely sensitive to changes in adult survival (Ricklefs 1990, Ricklefs 2000). Population trends can result from changes in either productivity or survival, but most trends that have been investigated are attributed to changes in productivity. Such changes may have more to do with the difficulty of obtaining long-term demographic data on seabirds than from a clear link between trends and productivity. Many seabirds have life-history traits that favor adult survival over reproductive effort (Russell et al. 1999, Saether and Bakke 2000). For this reason, Russell et al. (1999) caution against relying on productivity studies to reach conclusions about population dynamics. For example, Weimerskirch et al. 1997 (cited and presented in Russell et al. 1999) showed an increased rate of decline in five wandering albatross populations corresponding to local increases in longline fishing effort. Furthermore, in long-lived animals, observable impact on the breeding population may take years or decades. One study, which modeled impacts of loss of juveniles from longline incidental catch, estimated it would take 5 to 10 years to detect the decline

Table 3.5-2 Population Trends of Alaskan Seabirds: Kittiwakes, Murres, and Guillemots

Location	Black-Legged Kittiwakes	Red-Legged Kittiwakes	Common Murres	Thick-Billed Murres	Pigeon Guillemots
Chukchi Sea	+		+	+	
Northern Bering Sea	0		0	?	?
Central & SE Bering Sea	--	--	+	0	?
Bristol Bay	0		0		?
Western Aleutian Islands	+	+	?	+	?
Central Aleutian Islands	0		0	?	?
Eastern Aleutian Islands	?		--	--	?
Western Gulf of Alaska	–		+	+	--
Northern Gulf of Alaska	–		–		--
Southeast Alaska			--		?

Notes: + – Increase
 0 – Stable
 – – Decline

? – trend unknown
 blank – Species not present

Other notes: Trends are shown for the last 5 to 20 years for species monitored for four years or more. See text for earlier trends. Each area covers about 500 km of coast and includes one or more monitoring sites. If trends vary among colonies in an area, the trend shown is for the area's overall population. No information on trends exists for terns or black guillemots. For sources, see text.

Table 3.5-3 Population Trends of Alaskan Seabirds: Auklets, Murrelets, and Puffins

Location	Least Auklets	Crested Auklets	Kittlitz's Murrelets	Marbled Murrelets	Tufted Puffins
Chukchi Sea			?		?
Northern Bering Sea	?	?	?		?
Central & SE Bering Sea	?	?			?
Bristol Bay			?	?	?
Western Aleutian Islands	?	?	?	?	?
Central Aleutian Islands	--	0	?	?	?
Eastern Aleutian Islands	?	?	?	?	+
Western Gulf of Alaska	?	?	?	?	?
Northern Gulf of Alaska			--	--	0
Southeast Alaska			?	?	?

Notes: + – Increase
 0 – Stable
 – – Decline

? – trend unknown
 blank – Species not present

Other notes: Trends are shown for the last 5 to 20 years for species monitored for four years or more. See text for earlier trends. Each area covers about 500 km of coast and includes one or more monitoring sites. If trends vary among colonies in an area, the trend shown is for the area's overall population. No information on trends exists for other auklets, ancient murrelets, rhinoceros auklets, or horned puffins. For sources, see text.

Table 3.5-4 Population Trends for Kittiwakes and Murres at Selected Breeding Colonies in the Bering Sea

Location	Species ^a	Years ^b	Range	Overall Trend ^c	Subset Trends ^d
Agattu	BLK1	8	1975–1994	Increase ($r^2 = 0.63$, $p < 0.02$)	75–79 < 88–94 ($t = 2.746$, $p < 0.03$), No trend 88–94 ($r^2 = 0.03$)
	UNMU	7	1974–1994	Increase ($r^2 = 0.55$, $p < 0.06$)	74–79 < 85–94 ($t = 5.086$, $p < 0.01$), No trend 85–94 ($r^2 = 0.07$)
Buldir	BLK1	10	1974–1996	Increase ($r^2 = 0.87$), $p < 0.01$)	74–76 < 88–96 ($t = 12.109$, $p < 0.01$), No trend 88–96 ($r^2 = 0.14$)
	RLK1	10	1974–1996	Increase ($r^2 = 0.84$), $p < 0.01$)	74–76 < 88–96 ($t = 9.96$, $p < 0.01$), No trend 88–96 ($r^2 = 0.15$)
	TBMU	10	1974–1996	Increase ($r^2 = 0.86$), $p < 0.01$)	74–76 < 88–92 < 94–96 ($F = 155.529$, $p < 0.001$)
Cape Pierce	BLK1	13	1976–1996	No trend ($r^2 = 0.01$)	
	COMU	13	1976–1996	No trend ($r^2 = 0.10$)	
Bluff	BLK1	14	1979–1995	Increase ($r^2 = 0.51$, $p < 0.01$)	No trend 87–95 ($r^2 = 0.07$)
	COMU ^e	8	1975–1982	Decline ($r^2 = 0.75$, $p < 0.01$)	
		12	1979–1995	No trend ($r^2 = 0.01$)	
Saint Paul	BLK1	10	1976–1996	Decline ($r^2 = 0.63$, $p < 0.01$)	No trend 87–96 ($r^2 = 0.31$)
	RLK1	10	1976–1996	Decline ($r^2 = 0.75$, $p < 0.01$)	No trend 88–96 ($r^2 = 0.78$, $p > 0.10$)
	COMU	10	1976–1996	Decline ($r^2 = 0.53$, $p < 0.02$)	No trend 86–96 ($r^2 = 0.11$)
	TBMU	10	1976–1996	No trend ($r^2 = 0.12$)	76 > 82–96 ($t = 10.051$, $p < 0.01$)
Saint George	BLK1	10	1976–1996	No trend ($r^2 = 0.24$)	Decline 76–86 ($r^2 = 0.89$, $p < 0.02$), No trend 87–96 ($r^2 = 0.64$, $p = 0.11$)
	RLK1	10	1976–1996	Decline ($r^2 = 0.64$), $p < 0.01$)	76–86 > 87–96 ($t = 2.086$, $p < 0.10$), No trend 87–96 ($r^2 = 0.01$)
	COMU	10	1976–1996	Increase ($r^2 = 0.48$), $p < 0.03$)	No trend 76–92 ($r^2 = 0.18$), increase based on 96 count
	TBMU	10	1976–1996	No trend ($r^2 = 0.23$)	Decline 76–88 ($r^2 = 0.94$, $p < 0.01$), apparent increase 89–96.

Notes: ^aCodes: BLK1 (black-legged kittiwake), RLK1 (red-legged kittiwake), COMU (common murre), TBMU (thick-billed murre), UNMU (unidentified murre, includes both species).

^bNumber of years and earliest and latest year for which data are available.

^cTrends indicated if simple linear models fit and slopes differed from zero at the 0.1 level.

^dTrends suggested on graphs for subsets at least four years long were tested with regressions, and subsets were compared with t-tests or ANOVA to identify differences.

^eSeparate data sets were analyzed for whole-colony counts (1975–1982) and plot counts (1979–1995).

Source: This table used with permission of the primary author, Table 1 in Hunt, G.L., Jr. and G.V. Byrd, Jr. 1999. "Marine bird populations and the carrying capacity of the eastern Bering Sea." Pp.631–650 in, T.R. Loughlin and K. Ohtani, eds. *The Bering Sea: Physical, Chemical and Biological Dynamics*. Alaska Sea Grant, University of Alaska, Fairbanks.

in breeding populations and 30 to 50 years for the population to stabilize after conservation measures were taken (Moloney et al. 1994). A major constraint on seabird breeding is the distance between the breeding grounds on land and the feeding zones at sea (Weimerskirch and Cherel 1998). Breeding success in most species varies among years, but in stable populations, poor success is compensated for by occasional good years (Boersma 1998, Russell et al. 1999). Fluctuations in fish stock recruitment are likely to affect the survival of adult seabirds differently than seabird reproduction. Adult seabird survival is unlikely to be affected by the common interannual variability of prey stock because adults can shift to alternative prey or migrate to seek prey in other regions. In contrast, breeding birds are tied to their colonies and local fluctuations in fish recruitment can have a dramatic effect on seabird reproduction. If food supplies are reduced below the amount needed to generate and incubate eggs, or if the specific species and size of prey needed to feed chicks are unavailable, local reproduction by seabirds will fail (Hunt et al. 1996c). The natural factor most often associated with low breeding success is food scarcity (Kuletz 1983, Murphy et al. 1984, Murphy et al. 1987, Springer 1991b, Furness and Monaghan 1987, Croxall and Rothery 1991, Cairns 1992). Seabird populations, therefore, are usually limited by food availability (Furness 1982, Croxall and Rothery 1991).

Foraging ecology differs among seabird species. Diets consist largely of fish or squid less than 15 cm long, large zooplankton, or a combination of both. Most seabirds in a given area depend on one or a few prey species (Springer 1991b). Diets and foraging ranges are most restricted during the breeding season, when high-energy food must be delivered efficiently to nestlings, and are somewhat more flexible at other times of the year. Seabird species differ greatly from one another in their requirements for prey and feeding habitats and, consequently, in their response to changes in the environment. Winter foraging ecology is not known for most species (Hunt et al. 1999). Seabird diets (Tables 3.3-1 and 3.3-2) and foraging ecology are described in Section 3.5.1.

The availability of prey to seabirds depends on a large number of factors and differs among species and seasons. All seabird species depend on one or more oceanographic processes that concentrate their prey at the necessary time and place; these include upwellings, stratification, ice edges, fronts, gyres, and tidal currents (Schneider et al. 1987, Coyle et al. 1992, Elphick and Hunt 1993, Hunt and Harrison 1990, Hunt 1997, review in Hunt et al. 1999, Springer et al. 1999). Prey availability may also depend on the ecology of food species, including productivity, other predators, food-web relationships of the prey, and prey behavior, such as migration of fish and zooplankton. Once prey is captured, its value depends on its energy content.

Many factors that influence prey availability are completely unknown, including stock size and fishery harvests. These considerations are further discussed in Section 3.5.2.

Access to prey is limited by each bird's foraging behavior and range, and by prey size, depth, and behavior. Prey availability and density within each seabird species' foraging range is likely a principal factor that determines whether seabird populations are stable, increasing, or declining. The relationships of birds to their prey are considered in Section 3.5.3.

Groundfish fisheries can impact seabird survival directly through incidental take in gear. Seabirds are caught in commercial fishing gear while attempting to seize baits or discards, or while pursuing their natural food in the vicinity of gear. The majority of seabird incidental catch in Alaskan groundfish fisheries takes place on longline gear, but trawlers also catch birds. Incidental catch is further discussed in Section 3.5.4.

Some seabird species scavenge discards from floating and onshore processors. Such behavior may make them vulnerable to being caught in gear. Large-scale exploitation of an artificial food source also can cause a seabird population to increase, which can result in major shifts within the avian food web. The impacts of discards are discussed in Section 3.5.5.

The presence of vessel traffic in Alaskan waters imposes the risk of accidents that can affect seabirds, and this risk would be influenced by changes in the number of groundfish vessel-days per year. Among the threats to seabirds are oil and fuel spills from collisions, groundings, and routine operations. Another threat from vessels is the introduction of rats to nesting islands from groundings or via ports; rats are voracious predators on young birds and can reduce seabird populations severely. Such risks are discussed in Section 3.5.6.

3.5.1 Seabird Life History, Population Biology, and Foraging Ecology

3.5.1.1 Northern Fulmar

Northern fulmars (*Fulmarus glacialis*) breed in Alaska from the Bering Sea to the GOA (USFWS 1998a). Ninety-nine percent of the Alaskan population resides in four colonies: Semidi Island, Chagulak Island in the Aleutian Islands, the Pribilof Islands, and Saint Matthew and Hall Islands (Hatch and Nettleship 1998). Populations in the Bering Sea have increased gradually over the past two decades (Table 3.5-1; Byrd and Dragoo 1997, Byrd et al. 1998 and 1999). One recent estimate indicates the fulmar population in the North Pacific to be 4 to 5 million individuals. The estimated species population worldwide is 10 to 12 million individuals (Hatch and Nettleship 1998).

Northern fulmars forage from the continental shelf to beyond the continental shelf break, ranging over large areas of ocean 100 km or more from breeding colonies (Hunt et al. 1981 c, Gould et al. 1982, Schneider and Hunt 1984, DeGange and Sanger 1986, Schneider et al. 1986, Hatch 1993). The foraging range is potentially large: the birds depart from the colony every four to five days on foraging trips, both before egg-laying and during incubation (Hatch and Nettleship 1998). They disperse throughout ice-free Alaskan waters and in the North Pacific Ocean in winter (Gould et al. 1982, Shuntov 1993). During the summer, prey include squid, myctophids, other fish (including juvenile pollock in the Pribilof Islands), zooplankton, jellyfish, and other invertebrates (Ainley and Sanger 1979, Hunt et al. 1981 a, DeGange and Sanger 1986, Sanger 1986, Schneider et al. 1986, Baird 1990, Hatch 1993, Gould et al. 1997). Fulmars also feed on debris from fishing and at-sea processing when available (Furness 1984).

Food is taken from the water surface or just beneath it, including at night when pelagic prey migrate close to the surface (Schneider et al. 1986, Hatch 1993). Fulmars probably do much of their foraging at night, and may use olfactory cues in locating food because their sense of smell is highly developed (Hatch and Nettleship 1998). Fulmars obtain food by dipping, surface-seizing, surface-plunging, pursuit-diving (uncommon method, probably only used by food-stressed individuals), and scavenging. They are apparently unable to pick up prey while on the wing. Prey (mesopelagic fish, squid, and crustaceans available in surface waters only at night) and daily activity patterns (evening departures and morning arrivals at colonies) indicate the importance of nighttime foraging, at least at lower latitudes (Hatch and Nettleship 1998). Night feeding has been directly observed in the Bering Sea.

Night sets during experimental tests of seabird mitigation measures showed significant increases of fulmar incidental catch (E. Melvin, Washington Sea Grant, University of Washington - personal communication). The estimated annual longline mortality of fulmars (9,309 individuals) represents a small percentage (0.4 percent) of the estimated Alaskan breeding population of over 1 million pairs, and only 0.2 percent of the total estimated Pacific population of 4.6 million birds, including those that breed in Asia and nonbreeding birds (Hatch and Nettleship 1998). Thus incidental catch of fulmars is not thought to be a serious conservation problem. See Section 3.5.4.1 for current estimates of incidental catch in the hook-and-line groundfish fisheries in the BSAI and GOA.

3.5.1.2 Storm-petrels

Two storm-petrel species breed in Alaska: Leach's storm-petrel (*Oceanodroma leucorhoa*) and the fork-tailed storm-petrel (*O. furcata*). Both breed on islands from the western Aleutian Islands through the GOA, but not farther north (USFWS 1998a). Most species are active at the colony only at night, and often stay at sea during the day or on moonlit nights (Boersma and Groom 1993). Populations are increasing in the Aleutian Islands and southeast Alaska (Table 3.5-1; Byrd et al. 1998 and 1999).

Storm-petrels forage at distances of more than 100 km from breeding colonies and typically forage over the shelf edge and deep water (Springer et al. 1999). Fork-tailed storm-petrels most typically forage over the outer shelf and adjacent ocean. This species has also been observed feeding on the southeast Bering Sea shelf near the Slime Bank area and in large groups in Resurrection Bay coming out of Seward (C. Baduini, University of California, Irvine - personal communication). Leach's storm-petrels forage from the shelf-break seaward (Ainley and Sanger 1979, Hunt et al. 1981a, Gould et al. 1982, Schneider et al. 1986). Storm-petrels winter over the deep ocean, including the Bering Sea Basin (Shuntov 1993). Storm-petrels seize prey from the water's surface and forage at night. They have well-developed olfactory systems and find their food, and perhaps nest sites by scent (Boersma and Groom 1993). Storm-petrels feed on small fishes, particularly juvenile lantern fish, squid, and euphausiids (Springer et al. 1999), but in some areas, fork-tailed storm-petrels may depend on small fish such as capelin (Ainley and Sanger 1979, Baird and Gould 1986, Sanger 1986).

The key to population stability in storm-petrels appears to be high adult survivorship. Any perturbations that greatly depress their low reproductive output could lead to population decline, particularly if lowered output results in low recruitment into the adult life stage. Threats that severely reduce adult survivorship or greatly lower reproductive success could cause storm-petrel populations to decline (Boersma and Groom 1993).

3.5.1.3 Albatross

The three North Pacific albatrosses are Laysan's (*Diomedea immutabilis*), black-footed (*D. nigripes*), and short-tailed (*D. albatrus*). All three breed in the subtropics during winter: Laysan's and black-footed albatrosses breed in the northwestern Hawaiian Islands and the short-tailed albatross breeds primarily on the island of Torishima in Japan. Albatrosses spend the summer (approximately May through September) in Alaskan waters, although some nonbreeding birds may be encountered at any time. Laysan's albatross occurs from Japan to North America, and from the southern Bering Sea to the Hawaiian Islands (Shuntov 1972).

Numerous studies have noted that Laysan's albatross are more frequently observed at and seaward of the continental slope, over areas of strong, persistent upwelling, and at the boundaries between different water masses (review in McDermond and Morgan 1993). The preferred habitats of the Laysan's albatross may in part be related to food distribution. Given that they feed more predominantly on squid, and that squid distribution may in turn be determined by the distribution and abundance of euphausiid, it has been suggested that it is the restriction of large euphausiids to cold waters that determines the southern limits of this species (McDermond and Morgan 1993).

The maximum range of the black-footed albatross are the coasts of China, Japan, and Russia east to continental North America; and from the Sea of Okhotsk and the Bering Sea south to about 18°N and occasionally to 10°N in the central Pacific (Shuntov 1972). Although the central Pacific is considered to be the preferred wintering area for nonbreeding adults, low numbers of black-footed albatross are found in the eastern temperate North Pacific Ocean throughout the entire winter, as far north as 55°N (McDermond and Morgan 1993). Black-footed albatrosses are more abundant over the outer continental shelf, especially at the shelf break, than elsewhere. Areas with strong, persistent upwelling, or the boundaries of different water masses, are also

avored; their concentration over the continental slope may in part be a result of the distribution of fishing vessels in these areas (McDermond and Morgan 1993).

Relatively little is known about seasonal movements or factors determining marine distribution of the short-tailed albatross (McDermond and Morgan 1993). It is believed that the species was formerly common off China, in the Sea of Japan, the Sea of Okhotsk, the Bering Sea north to the Bering Strait, and throughout the entire temperate North Pacific Ocean, from Alaska to Baja California (McDermond and Morgan 1993, USFWS 1998b). Areas of high productivity, such as along the Pacific coast of North America, in the Aleutian Islands, and in the Bering Sea, were favored (Hasegawa and DeGange 1982). The USFWS currently maintains a short-tailed albatross sightings database, which contains sightings from 1905 (Figure 3.5-2). A brief summary of the sightings database is as follows:

- 655 sightings records.
- Sightings reported as far south as 19°N (off Mexico), as far north as 60°N, as far west as 134°E (off Japan), and as far east as 107°W (off Mexico).
- Over 90 percent of records are sightings of one or two birds (mostly single birds) and these sightings have been reported in all months of the year, as many as 40 short-tailed albatross were estimated in one sighting record, and most of the multiple sightings records occur in the month of September.
- Six times as many sightings are reported from fishing vessels as from research vessels, the next highest type of vessel reporting sightings.
- For those sightings, records that include age(s) of the bird sighted, four times more nonadults (juvenile, immature, and subadult) than adults were sighted.
- Recent sightings indicate short-tailed albatross frequenting areas around the Pribilof Islands and the western Aleutian Islands (C. Baduini, University of California, Irvine - personal communication, G. Balogh, USFWS, Anchorage - personal communication).

In Alaska, the Laysan's albatross are most abundant in the western Aleutian Islands, and black-footed albatross are most abundant in the GOA. Satellite telemetry studies on the foraging destinations of Laysan's and black-footed albatrosses from their primary breeding colonies in the northwestern Hawaiian Islands (Midway Atoll in particular) corroborates this pattern of Laysan's albatross traveling further north to the Aleutian Islands area and black-footed albatross foraging in waters to the south, in the GOA and off the western coast of the U.S. (D. Anderson, Wake Forest University - personal communication). Trends among nonbreeding birds (primarily subadults) are unknown. This is a problem for all seabird species, but it is especially serious for albatrosses, for which approximately one-half the population is nonbreeding.

The Laysan's albatross is the most numerous of the North Pacific albatrosses, with a worldwide population of approximately 2.5 to 3 million birds (Gales 1998). Given the relative abundance of this species compared to other albatross species, its status is generally considered to be relatively secure. However, of the 16 documented breeding sites, two populations, representing 93 percent of the total breeding stock, are known to be decreasing (Gales 1998). Since the 1970s, the Laysan's albatross has greatly expanded its presence in the southeastern Bering Sea; prior to then, it was highly unusual to encounter a Laysan's albatross in the Bering Sea, and most sightings occurred over the basin (G. L. Hunt, Jr., University of California, Irvine - personal communication). At present, Laysan's albatrosses are regularly encountered in and north of the passes through

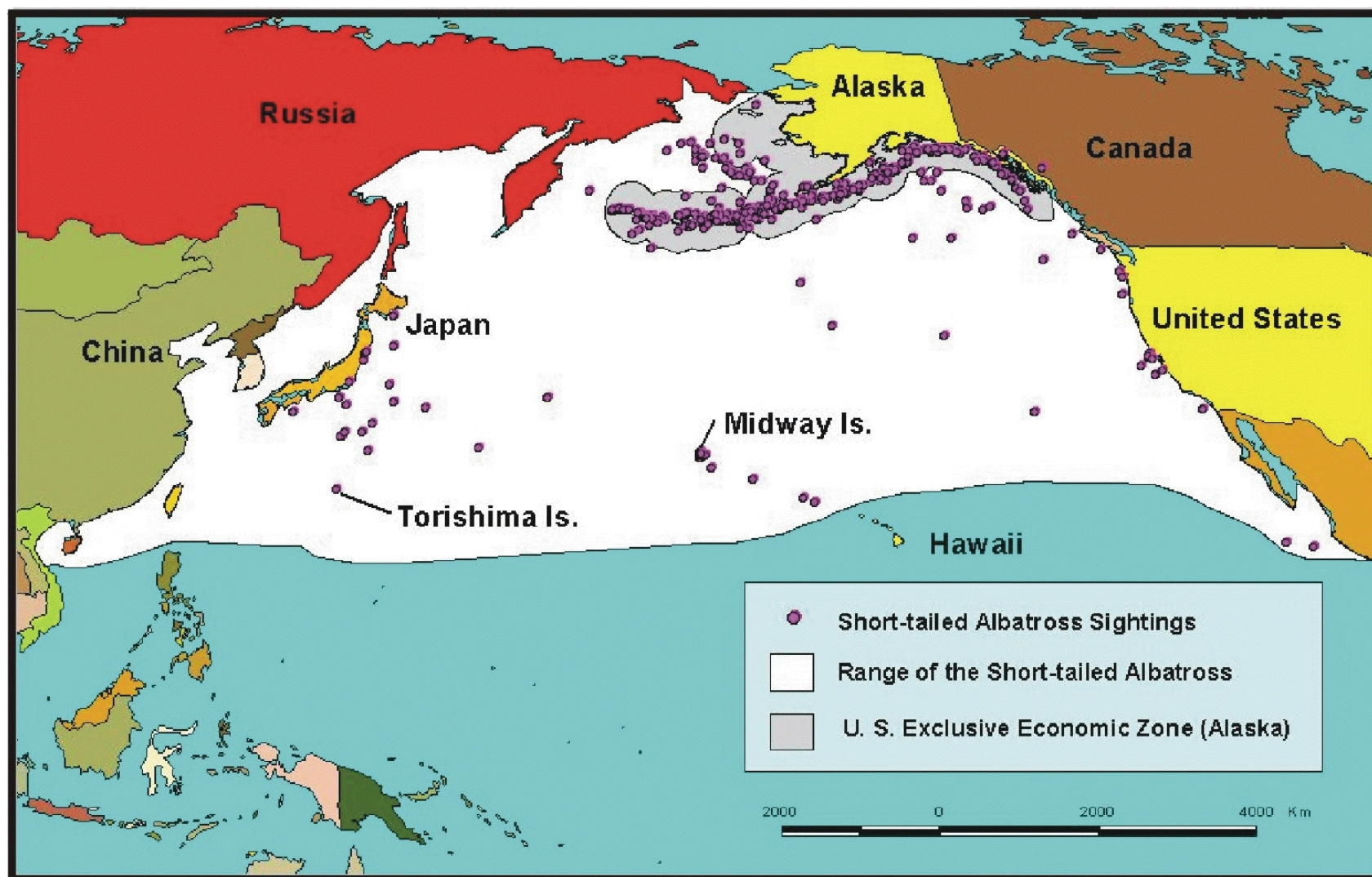


Figure 3.5-2 Short-tailed albatross distribution and sightings, 1905–1996. The birds can be in any part of their range during any months in which open water is present. Source: USFWS.

the Aleutian Islands, over the shelf north of the Alaska Peninsula, and along the shelf break as far as the Pribilof Islands, meaning that these birds are likely to attend even more vessels than may have previously been the case (G. L. Hunt, Jr., University of California, Irvine - personal communication). Various threats may affect the Laysan's albatross, but since the cessation of widespread harvesting of eggs and adults over 100 years ago and the end of the intensive control programs of the U.S. military, mortality associated with fishing interactions represent the most recent and potentially significant threat to the species (Gales 1998). See Section 3.5.4.1 for current estimates of incidental catch in the hook-and-line groundfish fisheries in the BSAI and GOA. Between 1994 and 1996, 1,156 Laysan's albatrosses were estimated to be killed annually by Hawaii-based longline vessels (Western Pacific Regional Fishery Management Council 1997).

The current world population of the black-footed albatross is approximately 240,000 to 290,000. The major populations are either decreasing or of unknown status. Five of the nine Hawaiian populations (representing 47 percent of the world population) are decreasing, and the others are of unknown status (Gales 1998). In addition to past disturbances at breeding colonies and high levels of take in the now-closed North Pacific high-seas driftnet fisheries, recent threats to the black-footed albatross population include plastic ingestion, exposure to contaminants, and mortality from fishery interactions (Cousins and Cooper submitted). Noting the report rates of decline in many of the northwest Hawaiian breeding colonies (where 96 percent of the world population resides), Croxall and Gales (1998) assigned black-footed albatross vulnerable status under the World Conservation Union (IUCN) criteria. See Section 3.5.4.1 for current estimates of incidental catch in the BSAI and GOA hook-and-line groundfish fisheries. Between 1994 and 1998, 1,831 black-footed albatrosses were estimated to be killed annually by Hawaii-based longline vessels (Cousins and Cooper submitted).

The short-tailed albatross is listed as endangered under the Endangered Species Act (ESA). Its population was drastically reduced early in the century by commercial harvest (Hasegawa and DeGange 1982) and now numbers only about 600 breeding birds; the total population probably is about 1,300 (H. Hasegawa, Toho University, Japan - personal communication). Based on egg counts from 1980 to 1998, the population on Torishima Island, Japan (the main breeding site) is increasing at an annual rate of 7 to 8 percent (J. Cochrane, USFWS, Grand Marais - personal communication). Although the short-tailed albatross population is increasing, it is still extremely vulnerable because of its small size and the fact that it breeds on only two islands near Japan, one of which is an active volcano.

Cephalopods play a major role in the diets of nine albatross species investigated, including the Laysan's and black-footed albatrosses (Cherel and Klages 1998). The squid families Ommastrephidae and Onychoteuthidae are the most important food in the albatross diets, although the species of ommastrephids eaten by Laysan's and black-footed albatrosses are poorly known. All three albatrosses forage along the edge of the continental shelf because their prey are abundant in upwellings there. Short-tailed albatross also forage on the outer shelf. Few observations have been published of Laysan's and black-footed albatrosses feeding in the wild, other than by scavenging near vessels and in association with the high-seas driftnet fisheries. Both species have been reported to take food in the upper 1 m of the ocean by surface seizing, contact dipping, and scavenging (Gould et al. 1998). All three species seize prey from the surface, or just below it, while sitting on the water. Laysan's and black-footed albatrosses feed on myctophids, squid, and other invertebrates and fish. In one study of the food habits and driftnet fisheries, associations of nonbreeding Laysan's and black-footed albatrosses prior to the cessation of the driftnet fisheries in 1992, fishes were more numerous than squid in the diets of nonbreeding Laysan's, while squids were more important than fishes in the diets of nonbreeding black-footed albatrosses (review in Gould et al. 1998). This differs from a study of the diet components of chicks and breeding birds in Hawaii where squid was the main component of diet fed to Laysan's chicks while fish (primarily fish eggs) was the main component of the diet of black-footed chicks (Harrison et al. 1983).

Albatross breeding status and association with fisheries (i.e., availability of an additional food source) appears to effect prey choice. Short-tailed albatrosses take similar foods and may forage at night (Sherburne 1993). Laysan's albatrosses have better night vision, longer bills, and longer but lighter bodies than black-footed albatrosses. Laysan's albatrosses may be more capable than black-footed albatrosses of rapid retrieval of small prey that are active in surface waters at night. The heavier and more compact black-footed albatrosses, with their shorter, stockier bills, may be better adapted to scavenging naturally occurring large carrion or refuse from ships (Gould et al. 1998). All three albatrosses are attracted to debris behind fishing vessels and processors and are vulnerable to being caught by longlines (see Section 3.5.4).

Designations as diurnal or nocturnal feeders are indirect and based primarily on diet composition. In the absence of driftnet fishing, the diet needs critical reexamination, as does designations as diurnal or nocturnal feeders. One recent study incorporated the use of immersion monitors to study the foraging movements (Fernandez and Anderson 2000). Because albatrosses must enter the water to obtain food, immersion frequency should be correlated with feeding effort. Data collected was used to characterize the foraging patterns of Laysan's and black-footed albatrosses during the incubation and chick-brooding stages of the breeding cycle. Monitors were retrieved only from males. The data suggested both species split their foraging time between nocturnal and diurnal foraging. Daytime foraging appears to be more important for these two albatross species, and especially for Laysan's albatross, than has previously been recognized (Fernandez and Anderson 2000). Data from females, breeders during other parts of the reproductive period, and nonbreeders, plus food samples, will be required to fully characterize the relative importance of diurnal versus nocturnal foraging in Hawaiian albatross species (Fernandez and Anderson 2000). No similar data exist for the short-tailed albatross.

Satellite tagging and telemetry studies are increasingly being used to determine albatross foraging areas in the Southern Hemisphere (review in Gremillet et al. 2000). One species, the black-browed albatross (*Thalassarche melanophrys*), relies on the marine resources of the Patagonian shelf, a highly productive continental shelf that has experienced a rapid development of commercial fisheries. Significant spatial-temporal overlap occurs between human and albatross fishing activities within the Patagonian shelf. Potential detrimental effects on the albatross population could be competition for food and additional longline mortality (Gremillet et al. 2000). In 1989 and 1999, satellite telemetry studies were initiated to determine the spatial distribution of 54 breeding Laysan's and black-footed albatrosses nesting in the northwestern Hawaiian Islands and Kilauea Point National Wildlife Refuge. Both species mixed short foraging trips near the nesting island with much longer trips, trackings being made during the months of January to June. Laysan's albatross traveled primarily to the north on long trips, frequently reaching the Aleutian Islands and GOA. Long trips of black-footed albatross typically ended on the California, Oregon, and Washington State coasts (Anderson et al. 2000). Thus, based on satellite telemetry data, breeding Laysan's albatrosses are known to forage in waters off Alaska. It is possible that breeding black-footed albatrosses may also forage as far as Alaska.

In its biological opinion on the effects of the Pacific halibut fishery off Alaska, the USFWS (1998c) recognized that changes in the Bering Sea trophic system have been implicated in the decline of several marine species. USFWS found it impossible to determine whether indirect take of short-tailed albatross was resulting from ecosystem perturbations caused by the fishery. Because the population on Torishima Island appears to be increasing at near-maximum biological potential, it seems that the species is not limited by food quantity or quality.

A better understanding of the feeding preferences and foraging habits of these species, along with a better knowledge of their distribution at sea, is necessary in order to understand and predict fishery impacts.

3.5.1.4 Shearwaters

Short-tailed (*Puffinus tenuirostris*) and sooty (*P. griseus*) shearwaters breed in the Southern Hemisphere, the former in southeastern Australia and Tasmania and the latter in New Zealand and in Chile along the South American coast. Both short-tailed and sooty shearwaters visit Alaskan waters from May through September. Sooty shearwaters range primarily south of the Aleutian Islands and in the GOA, and short-tailed shearwaters are found in the Bering and Chukchi Seas as well as the GOA (Hunt et al. 1981a, Gould et al. 1982). An overall decreasing trend in sooty and short-tailed shearwater abundance at colonies has occurred over the past 20 to 30 years (C. Baduini, University of California, Irvine - personal communication). The mechanism(s) for these declines have yet to be understood. Numerous potential causes have been identified: fisheries bycatch, overfishing of important seabird prey species, climatic anomalies (such as El Niño events) disrupting marine foodwebs, and long-term harvesting of chicks. These are potentially cumulative impacts, which could decrease these seabird populations (Lyver et al. 1999). Three different time-series of pelagic bird abundance collected in disparate portions of the California Current reveal a 90 percent decline in sooty shearwater abundance between 1987 and 1994; the decline is negatively correlated with a concurrent rise in sea-surface temperatures (Veit et al. 1996 and 1997). The widely separated surveys suggest that this population change is occurring at a global scale in the sense that the worldwide population of sooty shearwaters seems likely to have been affected. The populations of these two species in Alaskan waters in summer account for over 50 percent of all seabirds combined (Sanger and Ainley 1988).

Shearwaters in the southeastern Bering Sea have, in the past, consumed a large biomass of euphausiids. Recent evidence (Baduini et al. 2000) suggests that, since 1997, short-tailed shearwaters over the southeastern Bering Sea shelf have been taking increasing amounts of fish. Inshore of the inner front, Pacific sand lance is taken, whereas most foraging flocks offshore of the inner front were focused on age-0 gadids, most likely pollock. This apparent dependence on age 0 pollock may occur when euphausiids are scarce over the middle domain (Hunt et al. 1998).

Short-tailed shearwaters occasionally die-off in large numbers during late summer, apparently due to widespread scarcity of prey during anomalous oceanographic conditions. The recent large-scale die-off of short-tailed shearwaters suggests that these birds are vulnerable to changes in the abundance or availability of their preferred foods in the southeastern Bering Sea (Vance et al. 1998). Changes in water temperature or productivity may influence the abundance of euphausiids either directly, through bottom-up effects, or indirectly through changes in the distribution of predators that compete with shearwaters for euphausiids. When euphausiids are scarce, shearwaters can use age 0 pollock, if they are present in high concentrations. Shearwater use of age 0 pollock may need to be considered in future management decisions (G.L. Hunt, Jr., University of California, Irvine – personal communication). Major die-offs were recorded in Alaska in 1983, 1986, and 1997 (Nysewander and Trapp 1984, Irons et al. 1986, Hatch 1987, Baduini et al. 1998, Mendenhall et al. 1998). In 1997, a die-off of short-tailed shearwaters was estimated at 11 percent of the population surveyed; the birds apparently died of starvation (Baduini et al. 2000). This estimate was based on a count of floating carcasses in the southeast Bering Sea as a percent of the population surveyed. In 1998, anomalous climate conditions were repeated for a second consecutive year, with elevated temperature the water, cross-shelf advection of zooplankton and larval fish, major changes in the structure of the zooplankton community, and an unprecedented second observation of a large-scale coccolithophorid phytoplankton bloom (Hunt et al. 1999). Although no unusual mortality of short-tailed shearwaters was seen, birds were underweight. In both years, shearwater diets were broader than in previous years, with fish becoming a dominant prey in 1998. Major changes in the zooplankton community will be likely to affect other higher trophic level species, including fish and whales (Hunt et al. 1999).

Both shearwaters forage on the surface and dive to at least 60 m (Weimerskirch and Sagar 1996, Weimerskirch and Chérel 1998). The short-tailed shearwater eats primarily large euphausiids and some jellyfish and small schooling fish (Marchant and Higgins 1990). Diets of short-tailed shearwaters in spring varied by region in the western subarctic. Fish were the most important items everywhere except the western Subarctic Current and West Wind Drift, where squid dominated (Springer et al. 1999). The fish species consumed were mostly juvenile *Pleurogrammus* species and small-sized lantern fishes (Myctophidae). Euphausiids, squid, and copepods ranked second, third, and fourth, respectively, in weight as components of their diet (Springer et al. 1999). The diets of short-tailed shearwaters in the western subarctic apparently reflect the availability of prey species rather than dietary preferences, since elsewhere (e.g., Sea of Okhotsk and Bering Sea) other prey predominate (Ogi et al. 1980). Shearwaters depend on areas where prey are concentrated by upwellings, convergences, or bottom terrain features, especially along the inner front (Hunt et al. 1981a, Schneider et al. 1986, Hunt et al. 1996c). Sooty shearwaters eat primarily small schooling fish, such as Pacific saury, and myctophids and their movements are believed to coincide with the movements of the sauries (Ogi 1984). Sooty shearwaters forage on squid on the outer shelf and shelf break (DeGange and Sanger 1986) and with increasing prominence at higher latitudes (Ogi 1984).

3.5.1.5 Cormorants

Four species of cormorants breed in Alaska. The pelagic cormorant (*Phalacrocorax pelagicus*) breeds on all coasts of Alaska, the red-faced cormorant (*P. urile*) breeds west of Prince William Sound, and the double-crested cormorant (*P. auritus*) breeds in the Aleutian Islands and GOA. Brandt's cormorant (*P. penicillatus*) primarily breeds south of Alaska but has two small colonies in southeastern Alaska and one near the entrance to Prince William Sound (USFWS 1998a); it is not described further here. Populations are difficult to monitor because birds move frequently among colonies. Pelagic cormorant numbers are stable or increasing in Bristol Bay, the central Aleutian Islands, and southeast Alaska, but are declining at other sites in the Aleutian Islands, and the northern GOA. Red-faced cormorants are stable or increasing in the Pribilof Islands and central Aleutian Islands, but are declining in Bristol Bay, part of the Aleutian Islands, and the northern GOA (Table 3.3-1; Byrd and Dragoo 1997, Byrd et al. 1998).

Cormorants usually range within 20 km of shore (Schneider and Hunt 1984); winter distributions are similar except that birds move to ice-free coasts. Cormorants forage by diving as deep as 40 m (DeGange and Sanger 1986). All species of cormorants specialize on some combination of small schooling or nonschooling fish, such as capelin, Pacific sand lance, and demersal or bottom-dwelling species, and crustaceans. The pelagic cormorant consumes minor amounts of juvenile pollock (Siegel-Causey and Litvinenko 1993).

3.5.1.6 Jaegers

The three species of jaegers (*Stercorarius longicaudus*, *S. parasiticus*, and *S. pomarinus*) forage on shore during the summer and are primarily present in Alaskan marine waters during their spring and fall migrations. Jaegers winter in the Southern Hemisphere. Population trends for jaegers are unknown. The principal marine foods for jaegers are small schooling fish such as capelin and Pacific sand lance, most caught by themselves, with some taken from other seabirds while in the air (Gabrielson and Lincoln 1959, Sanger 1986).

3.5.1.7 Gulls

Seven species of gulls are common in Alaska. Two large species are common at sea in all seasons: the glaucous gull (*Larus hyperboreus*) and glaucous-winged gull (*L. glaucescens*). Glaucous gulls breed from Bristol Bay northward, and glaucous-winged gulls breed from the central Bering Sea southeastward. Herring gulls (*L. argentatus*) are also locally present near the Bering Strait and in the GOA. The principal small gulls in Alaskan waters are the mew gull (*L. canus*) and Bonaparte's gull (*L. philadelphia*) south of the Bering

Strait, and Sabine's gull (*Xema sabini*) from Bristol Bay northward (USFWS 1998a). Glaucous-winged gulls are monitored in some areas; they are declining in the western Aleutian Islands, but are stable or increasing in the eastern Aleutian Islands, northern GOA, and southeastern Alaska (Table 3.5-1 [Byrd et al. 1998]). Large gulls may increase locally near fish processors and dumps (Patten and Patten 1982).

Gulls forage both nearshore and at the shelf edge during the summer, and food is also taken onshore when available. In winter, most gulls disperse across the shelf from the ice edge to the deep ocean (Gould et al. 1982, DeGange and Sanger 1986, Schneider et al. 1986, Shuntov 1993). A variety of prey are taken from the surface of the water or ground, including small schooling fish such as capelin, Pacific sand lance, herring, and invertebrates. In addition, detritus is scavenged where available, as well as naturally occurring carrion and discards at fish processors and dumps (Patten and Patten 1982, Furness 1984, Murphy et al. 1984, Baird and Gould 1986). Large gulls also prey on eggs and young of waterfowl and seabirds (Swartz 1966, Baird and Gould 1986, Bowman et al. 1997). They are attracted to bait and discards behind fishing vessels, which exposes them to the risk of incidental take (Section 3.5.4).

Scavenging by gulls can influence population trends in both directions. Section 3.5.5 presents a more detailed description of the importance of processing wastes and discards in the diets of gulls.

3.5.1.8 Kittiwakes

Kittiwakes are small gulls that are specialized for pelagic feeding. The black-legged kittiwake (*Rissa tridactyla*) breeds throughout Alaska except for the southeast; the red-legged kittiwake (*R. brevirostris*) is restricted to four colonies in the BSAI (USFWS 1998a).

Kittiwake population trends differ among regions of the state ([Hunt and Byrd 1999], Table 3.5-4). Populations of both species on the Pribilof Islands declined steeply after 1976 (the year when monitoring began); red-legged kittiwakes declined to approximately half their original numbers. Although, as of 1997, it appears that kittiwake populations on Saint George Island have stabilized, it is not clear that the population of either species (particularly red-legged) on Saint Paul Island has stabilized (Hunt and Byrd 1999). These species appear to depend on fatty species of forage fish as well as age-0 and age-1 pollock for successful reproduction (Hunt et al. 1996c). The abundance of capelin and age-1 pollock near the Pribilof Islands has declined dramatically since the mid-1970s (Hunt et al. 1996e). Trends in the populations of myctophids and Pacific sand lance are not known. In contrast, both species have increased steadily in the western Aleutian Islands (Agattu and Buldir colonies) until the present. Black-legged kittiwakes are stable or increasing in the northern Bering Sea (Bluff colony), Aleutian Islands, and parts of the northern GOA; however, populations are declining in Cook Inlet, Kodiak Island, and parts of Bristol Bay (Tables 3.5-2 and 3.5-4; [Byrd and Drago 1997, Byrd et al. 1998 and 1999]). Declines and population shifts have been ascribed to lack of sufficient food during the breeding season (Springer et al. 1986, Suryan et al. 1998b, Hunt and Byrd 1999). Furthermore, it has been hypothesized that the failure of the seabird populations on the Pribilof Islands to show enhanced reproductive performance subsequent to the reduction of breeding populations suggests that the carrying capacity of the southeastern Bering Sea declined for seabirds in the early 1980s and was reset at a new, lower level than had existed in the mid-1970s. Because kittiwake populations were apparently only affected at the Pribilof Islands, the mortality must have occurred when birds would have been near their colonies (Hunt and Byrd 1999).

Black-legged kittiwakes occasionally die-off in large numbers during late summer, apparently due to widespread scarcity of prey at the surface during anomalous oceanographic conditions. Major die-offs were recorded in Alaska in 1983 and 1997 (Nysewander and Trapp 1984, Hatch 1987, Mendenhall et al. 1998).

It has recently been hypothesized that the declines in both species of kittiwakes and thick-billed murre at Saint Paul and Saint George Islands were caused by large die-offs of adults from these populations (Hunt and Byrd 1999).

The red-legged kittiwake is a USFWS species of management concern, because 80 percent of its worldwide population nests in only one colony, Saint George Island, and because its recent severe decline has not been explained (USFWS 1995b).

Black-legged kittiwakes forage over the entire continental shelf and shelf break; red-legged kittiwakes forage from the shelf break seaward; the foraging range during the breeding season is 100 km or more (Schneider and Hunt 1984, Schneider et al. 1986, Hatch 1993). Both also forage locally near the coast if schooling prey are available (Schneider et al. 1990, Suryan et al. 1998b, Suryan et al. 2000). Black-legged kittiwakes require a shelf several tens of kilometers wide and are few or absent in colonies with a very narrow shelf (Springer et al. 1996, Byrd et al. 1997). Black-legged kittiwakes winter over the shelf and deep ocean (Gould 1983, Shuntov 1993); the wintering area of the red-legged kittiwake is completely unknown. Prey are taken at the surface or by dives within a meter of the surface. Both consume small schooling fish and zooplankton, relying primarily on fish when feeding their young.

The principal fish prey of black-legged kittiwakes are capelin and Pacific sand lance, herring or small cods in some locations, and myctophids as well as juvenile pollock in the central Bering Sea. Black-legged kittiwakes also consume processing wastes in the North Sea when larger seabirds are not numerous near vessels (Furness and Ainley 1984). Little is known about scavenging by this species in Alaska. Red-legged kittiwakes consume the same fish but with more emphasis on myctophids and zooplankton (Hunt et al. 1981a, Springer et al. 1984, Springer et al. 1986, Springer et al. 1987, Sanger 1987a, Hatch 1993). Myctophids (Hatch 1993) and probably zooplankton, are taken primarily at night.

Capelin and Pacific sand lance vary greatly in availability among years, and breeding success in most areas is correlated with abundance of one or the other species in the diet (Troy and Baker 1985, Baird and Gould 1986, Springer et al. 1987, Baird 1990). Similarly, the availability of juvenile herring affects kittiwake foraging efforts and breeding success in Prince William Sound (Suryan et al. 2000). For kittiwake colonies in low productivity areas, the availability of all three forage species (capelin, Pacific sand lance, and herring) may be important to maintaining productivity (Suryan et al. 2000). Consumption of juvenile pollock, although prominent kittiwake diet in the Pribilof Islands in some years, results in slower chick growth than other principal forage fish, which have a higher energy content (Romano et al. 1998). Black-legged kittiwakes scavenge discards behind vessels to some extent (described in Section 3.5.4). Winter diets are poorly known; both species probably rely more on invertebrates in winter than when feeding young (Hatch 1993).

3.5.1.9 Terns

Arctic (*Sterna paradisaea*) and Aleutian (*S. aleutica*) terns breed in all marine regions of Alaska (USFWS 1998a). The Arctic tern migrates to the subantarctic for the winter. The wintering grounds of the Aleutian tern are at sea, although the location is unknown. Populations are not monitored in Alaska. Terns forage in coastal waters within a few miles of their colonies. They feed on the surface, or just beneath it, on small schooling fish (capelin, Pacific sand lance) and zooplankton. Fish are essential diet components when terns are feeding their young (Hunt et al. 1981c, Baird and Gould 1986, DeGange and Sanger 1986, Baird 1990).

3.5.1.10 Murres

Common murres (*Uria aalge*) breed in all marine regions of Alaska; thick-billed murres (*U. lomvia*) are found primarily in the Aleutian Islands, Bering Sea islands, and north of the Bering Strait (USFWS 1998a). Birds from colonies north of the Bering Strait winter in the central Bering Sea (Shuntov 1993, Hatch et al. 1996).

Murre population trends differ among regions (Table 3.5-4). Both species are monitored together in some areas. Common murres have increased steadily until the present in the Chukchi Sea and on Saint George Island (Byrd and Dragoo 1997, Byrd et al. 1998, 1999). Elsewhere in most of Alaska, common murres decreased at one time or another during the 1980s, but they now appear stable or display no overall trend, including in the northern Bering Sea, Saint Paul Island, Bristol Bay, and eastern Aleutian Islands (Murphy et al. 1986; Byrd and Dragoo 1997, Byrd et al. 1998, Hunt and Byrd 1999). Trends vary among GOA sites (Table 3.5-2, [Byrd and Dragoo 1997, Byrd et al. 1998 and 1999]). Thick-billed murres have increased north of the Bering Strait and in the western Aleutian Islands, decreased throughout the Pribilof Islands in the 1980s but are now stable or increasing, and are decreasing in the northern Bering Sea (Tables 3.5-2 and 3.5-4; [Byrd and Dragoo 1997, Byrd, Dragoo et al. 1998 and 1999]).

Common murres occasionally die-off in large numbers during winter and early spring, apparently due to widespread scarcity of prey during anomalous oceanographic conditions. Major die-offs were recorded in Alaska in 1970, 1993, and 1998 (Bailey and Davenport 1972, Piatt and van Pelt 1997, Mendenhall et al. 1998). It has recently been hypothesized that declines in both kittiwake species and thick-billed murres at Saint Paul and Saint George Islands were caused by large die-offs of adults from these populations (Hunt and Byrd 1999).

Murres forage over the continental shelf, particularly in small areas where benthic terrain, currents, or upwellings create local prey concentrations. Unusually high concentrations of both species of murres are known to regularly forage on euphausiids over a submarine ridge on the east side of Saint George Island (Coyle et al. 1992). In the southeastern Bering Sea in April, thick-billed murres concentrated in the outer shelf zone, an area characterized by pelagic fauna; common murres were more commonly found inshore of the middle front (Woodby 1984). The euphausiids may have been concentrated on the ridge by a combination of their diurnal vertical migration behavior and tidal advection. Whatever the mechanism, a substantial portion of the resident murre population forages here. Thus, these sites are important sources of energy for the nearby breeding colonies (Coyle et al. 1992). Thick-billed murres also forage over the outer shelf and shelf edge (Hunt et al. 1981, Kinder et al. 1983, Schneider and Hunt 1984, Schneider et al. 1986, Schneider et al. 1990, Shuntov 1993, Decker and Hunt 1996). Common murres require a shelf at least several tens of kilometers wide and are few or absent in colonies with a very narrow shelf; in contrast, thick-billed murres tend to occupy areas near a shelf edge, although they also breed in a few northern colonies on broad shelves (Springer et al. 1996, Byrd et al. 1997, USFWS 1998a). Common murres have a foraging range of approximately 50 to 80 km. Thick-billed murres range up to 100 km; and dive as deep as 200 m (Schneider and Hunt 1984, Bradstreet and Brown 1985, Piatt and Nettleship 1985, Hatch et al. 1996). They are highly dependent on densely schooling prey (Cairns and Schneider 1990, Piatt 1990, Mehlum et al. 1996). Common murres consume small fish, especially energy-rich species such as capelin and Pacific sand lance; other diet components include some zooplankton, juvenile pollock in the central Bering Sea, and small cod in northern regions. Thick-billed murres eat the same fish, in addition to myctophids, and larger numbers of zooplankton and other invertebrates as do common murres (Hunt et al. 1981a, Vermeer et al. 1987, Sanger 1987b, Elliott et al. 1990, Schneider et al. 1990). Thick-billed murres nesting in the western Aleutian Islands feed primarily on squid (Springer et al. 1996).

3.5.1.11 Guillemots

The pigeon guillemot (*Cephus columba*) breeds in most marine areas of Alaska south of the Bering Strait. The black guillemot (*C. grylle*) breeds north of the Bering Strait (USFWS 1998a) and winters in the Bering Sea. Populations are monitored only for pigeon guillemots in the northern GOA, where the population has declined over the past two decades, possibly due to reductions in prey availability (Table 3.5-2, [Hayes and Kuletz 1997]). However, their nearshore, benthic foraging behavior and tendency to socialize on intertidal rocks also makes them susceptible to oil spills (Oakley and Kuletz 1996).

Guillemots forage in coastal waters during the breeding season, within 10 km of the colony (Ewins et al. 1993, G. Golet, USFWS, unpubl. data). Pigeon guillemots winter in ice-free coastal waters; black and some pigeon guillemots winter at sea in and near the pack ice (Ewins et al. 1993, Carter et al. 1995, Shuntov 1993). Black guillemots dive to approximately 50 m (Piatt and Nettleship 1985) and pigeon guillemots up to 45 m (Ewins et al. 1993). The foraging ecology of pigeon guillemots has been studied in detail in Prince William Sound. The diet is diverse and includes small schooling fish such as capelin, sand lance, and herring, as well as bottom-dwelling fish and invertebrates (DeGange and Sanger 1986, Kuletz 1983, Golet et al. 2000). Benthic fish are a reliable food source but support only modest reproductive success. Schooling fish allow higher reproductive success (because their abundance and energy content are higher), but their availability fluctuates in time and space (Kuletz 1983, Golet et al. 2000). Pigeon guillemot chick growth and reproductive success (Golet et al. 2000) and population trends (Hayes and Kuletz 1997) are correlated with the availability of schooling species.

3.5.1.12 Auklets

The abundance and diversity of small auklets is much higher in the Bering Sea than elsewhere in the world, owing to the large-scale advection of oceanic zooplankton onto the shelf in areas such as the Aleutian passes and Bering Strait (Springer and Roseman 1985). Least (*Aethia pusilla*), crested (*A. cristatella*), and parakeet (*A. psittacula*) auklets breed from the Bering Strait to the Aleutian Islands and western GOA. Breeding colonies of least auklets are located, with few exceptions, on islands in or near oceanic water containing *Neocalanus plumchrus*, a type of copepod (Hunt 1997). The distance that least auklets commute between their colonies and foraging sites differs with the species of copepod sought and the distribution of the copepods in the water column (Hunt 1997). Cassin's auklets (*Ptychoramphus aleutica*) breed in the Aleutian Islands and western GOA; whiskered auklets (*A. pygmaea*) breed in the Aleutian Islands only. Least and crested auklets are the most abundant seabirds in the state (USFWS 1998a).

Population trends of auklets are poorly known at present because monitoring of their underground nests is difficult. Least auklets may be declining or stable in the central Aleutian Islands but increasing in the central and northern Bering Sea; crested auklets appear to be stable or increasing at these sites ([Springer et al. 1993], Table 3.5-3, [Byrd et al. 1998]). It has been suggested that auklet trends are due in part to food-chain changes following reductions in plankton-eating whales or other predators (Springer 1991b, Springer 1992, Springer et al. 1993). Other studies, however, indicate that decadal changes in primary productivity of northern versus southern Pacific waters have altered zooplankton abundance, which has not always resulted in population increases of seabirds (Francis et al. 1998, McGowan et al. 1998).

Auklets forage over the continental shelf or deep water, and winter over ice-free areas of the shelf up to 50 km from colonies (Hunt et al. 1990, Shuntov 1993, Springer et al. 1993). They seek water structures that concentrate small prey at depths of 5 to 30 m, such as pycnoclines, fronts, or tide rips over shallow sills (Hunt 1990, Hunt et al. 1990, Hunt et al. 1993). All forage by pursuit diving (Ashmole and Ashmole 1967). Least and whiskered auklets depend exclusively on large zooplankton, crested auklets eat large zooplankton and other invertebrates, and Cassin's auklets take similar prey along with squid and some small fish. Least auklets specialize on copepods, particularly *N. plumchrus*, and crested auklets specialize on euphausiids, particularly

Thysanoessa raschii (Hunt et al. 1998). The parakeet auklet is more generalized and eats a diverse diet of small schooling fish such as Pacific sand lance and juvenile pollock, jellyfish, squid, other invertebrates, and zooplankton (Hunt et al. 1993, Springer et al. 1993, Hunt et al. 1998). A recent study conducted in the shallow passes of the Aleutian Islands demonstrated that least, crested, and parakeet auklets timed their foraging in a pass to correspond with the presence of strong tidal currents and exhibited small-scale spatial segregation among the species (Hunt et al. 1998). Similarly, the diets of these three auklet species differed in composition despite the proximity of the areas in which they foraged. The researchers concluded that the three auklet species exhibited strong preferences for particular prey types, and that these prey preferences resulted in small-scale differentiation of preferred foraging sites. The strong tidal currents provided the energy for the close juxtaposition of different mechanisms for enhancing prey availability (Hunt et al. 1998). Similarly, spatial segregation of least and crested auklets in Anadyr Strait is thought to arise because of different physical mechanisms (fronts) causing concentrations of preferred prey originating at different depths (Russell et al. 1999). Numerous studies highlight the foraging ecology of auklets and relationships to physical oceanographic processes (Hunt and Harrison 1990, Russell and Hunt 1992, Hunt 1997, Hunt et al. 1998, Russell et al. 1999).

3.5.1.13 Murrelets

Kittlitz's murrelets (*Brachyramphus brevirostris*) breed from north of the Bering Strait to southeastern Alaska; marbled (*B. marmoratus*) and ancient (*Synthliboramphus antiquus*) murrelets breed from the Aleutian Islands eastward. Trends are known only for Prince William Sound. Kittlitz's murrelets have declined there since the 1970s (Kendall and Agler 1998). Marbled murrelets also declined between 1972 and 1984, but appeared to stabilize between 1989 and 1993, then declined further in 1996 and 1998 (Agler and Kendall 1997 and 1998, Lance et al. 1999). Marbled and Kittlitz's murrelets are designated as species of management concern by the USFWS due to population declines (USFWS 1995b).

Marbled murrelets forage in shallow waters within 5 km of shore and are associated with sites of upwellings or small fronts that might make prey available (Nelson 1997, Kuletz et al. 1995). Kittlitz's murrelets especially prefer inlets and forage near glaciers where available (Sanger 1987b, Ostrand et al. 1998, Day et al. 1999, Day and Nigro 2000). Ancient murrelets forage over the shelf and shelf break, but also occur near land at sites of tidal upwellings (Gaston 1994). Some murrelets winter in ice-free bays throughout the state; others apparently move south or offshore to unknown areas (Ewins et al. 1993, Carter et al. 1995). All three murrelets forage by diving. Marbled murrelets dive in water less than 50 m deep, but primarily less than 20 m deep (Nelson 1997). Diets are dominated by small schooling fish such as capelin and Pacific sand lance. Some zooplankton and other invertebrates are also consumed, more by Kittlitz's murrelet and especially by ancient murrelets (Sanger 1987b, Ewins et al. 1993, Springer et al. 1993, Gaston 1994).

3.5.1.14 Puffins

Horned (*Fratercula corniculata*) and tufted (*F. cirrhata*) puffins breed throughout Alaska's marine areas. Most winter south of Alaska over the deep ocean. The rhinoceros auklet (*Cerorhinca monocerata*, a misnamed puffin) breeds in the Aleutian Islands and GOA (USFWS 1998a). Tufted puffin populations have increased slightly in the central and eastern Aleutian Islands and southeastern Alaska; they were stable in the northern GOA during the 1990s (Table 3.5-3, [Byrd and Dragoo 1997, Byrd et al. 1998]). Trends of horned puffins and rhinoceros auklets are unknown.

Rhinoceros auklets and puffins forage both near shore and over the shelf, although rhinoceros auklets primarily feed near shore and puffins primarily feed on the shelf (DeGange and Sanger 1986, Schneider et al. 1986, Sanger 1987a). All three species dive for small schooling fish such as capelin, Pacific sand lance, and herring; horned and tufted puffins also consume pollock, squid, and zooplankton. The rhinoceros auklet may forage more often at twilight than other puffins. The tufted puffin has the most diverse diet of the three and consumes

the largest proportion of invertebrates (DeGange and Sanger 1986, Vermeer et al. 1987, Hatch and Sanger 1992, Byrd et al. 1997). Tufted puffin populations in Prince William Sound may partly be limited by low prey densities (Piatt et al. 1997).

3.5.1.15 Other Marine Birds

Several groups of marine-oriented birds that could potentially be affected by direct or indirect effects of the groundfish fishing industry inhabit the BSAI and GOA nearshore or offshore areas. These groups include Gaviidae (four loons), Podicipedidae (two grebes), Merganini (ten sea ducks), and Phalaropodidae (two phalaropes). The major sea ducks in this region include four species of eiders, harlequin ducks (*Histrionicus histrionicus*), oldsquaws (*Clangula hyemalis*), black scoters (*Melanittanigra*), surf scoters (*M. perspicillata*) and white-winged scoters (*M. fusca*). Of these sea ducks, eiders are of special interest because of recent population declines and because large portions of eider populations occur in areas potentially affected by the groundfish fisheries.

Common Eider

The Pacific race of the common eider (*Somateria mollissima*), the largest sea duck in North America, has declined severely as a breeding species in western Alaska since the late 1950s (Hodges et al. 1996) and probably in the Russian Far East since the early 1970s (Goudie et al. 1994). Common eiders, along with spectacled eiders, have exhibited a sharp decline in western Alaska, with numbers falling over 90 percent on the Yukon-Kuskokwim Delta (Stehn et al. 1993, Hodges et al. 1996). Common eiders are the southern-most breeding eider nesting from southeast Alaska, along the coast to the Canadian Arctic (Bellrose 1980). Population trend data on this eider are complicated by the lack of comprehensive nesting surveys (USFWS 1999a). Lack of comprehensive nesting surveys and standardized survey methods in coastal Alaska and in Canada confounds the interpretation of regional population trend data. Birds that summer east of Barrow, Alaska have been monitored sporadically through spring and fall migration watches at Point Barrow. Spring counts suggest that numbers of Pacific Eiders nesting in northern Alaska and the western Canadian arctic may have declined by 56 percent, from 156,100 in 1976 to 72,600 birds in 1996 (Suydam et al. 2000), although the counts may be subject to certain biases (Suydam et al. 1997) and should be viewed with caution.

The Pacific Eider declined severely as a breeding species in western Alaska since the late 1950's (Hodges et al. 1996) and probably in the Russian Far East since the early 1970s (Goudie et al. 1994). Eiders counted on the continental waterfowl breeding survey, primarily spectacled eiders and Pacific Eiders, have exhibited a sharp decline as a group in western Alaska with numbers falling over 90 percent on the Yukon-Kuskokwim Delta (Stehn et al. 1993, Hodges et al. 1996). King and Lensink (1971) proposed a possible summer population of 75,000 Pacific Eiders in Alaska based on averages from the continental survey, 1957–1970, with an estimated 51,000 on the principal breeding ground on the coast of the Yukon-Kuskokwim Delta. An estimated 5,000 breeding Pacific Eider were present on the Yukon-Kuskokwim Delta in 1996–1999 (Bowman et al. 1999) suggesting a dramatic overall decline may have occurred over the past two decades. Data from nest surveys and aerial breeding bird surveys since 1986 and 1988, respectively, indicate a stable or slightly increasing Pacific Eider population on the Yukon-Kuskokwim Delta.

Pacific Eiders nesting throughout the Aleutian Islands declined as a result of the introduction of foxes but later responded on some islands with the removal of foxes (Byrd 1992, Bailey 1993). Although an uncommon breeder along the Alaska Peninsula, Pacific Eiders may have declined sharply there (Gill et al. 1981).

Common eiders may overwinter in the Arctic Ocean but most of the Pacific race are believed to winter from the Bering Sea pack ice south to the Aleutian Islands (Byrd 1992), Kodiak Island (Larned and Zwiefelhofer 1995), Cook Inlet (Erikson 1977), and in Russia south to the Kuril Islands (Kistchinski 1973). The large polynya (a large area of open water surrounded by sea ice) associated with Saint Lawrence, Saint Matthew, and Nunivak Islands and the south side of the Seward Peninsula provide a winter refuge for common eiders, as well as other sea ducks such as oldsquaw and king and spectacled eiders (USFWS 1999a). Because these polynyas are located in relatively shallow water, they provide access to benthic invertebrate prey for these ducks.

King Eider

King eiders (*Somateria spectabilis*) are large, benthic-feeding sea ducks that have a circumpolar distribution, breeding in the high-arctic and wintering as far north as seas remain open (Bellrose 1980). The North American distribution center is the Beaufort Sea (Johnson and Herter 1989). The greatest concentration of nesting king eiders in Alaska is between the Colville River Delta and the Arctic National Wildlife Refuge (USFWS 1999a). They also nest on Saint Matthew and Saint Lawrence Islands in the Bering Sea. On the North Slope, there is no indication of a decline in the number of king eiders; the population appears to be stable or increasing in recent years (King and Brackney 1997, USFWS 1999a).

Spring staging areas in the Bering Sea are not well known (with the exception of Kvichak Bay, Alaska) since the eiders tend to migrate off shore (Larned 1998; USFWS 1999). Once they reach the southeastern Beaufort Sea in mid to late May, they stage in an open water lead off the west coast of Banks Island and to a lesser extent in a polynya off Cape Bathurst (Alexander et al. 1997). Preliminary data suggest Cape Bathurst is a key staging area for males during molt migration (Dickson et al. 1999).

Western arctic King Eiders molt primarily in the Bering Sea, and to a lesser extent in the Chukchi Sea (Kistchinski 1973; Dickson et al. 1999). Recent satellite telemetry has identified several key molting areas in the Bering Sea for North American breeders: off the south and east coasts of Chukotsk Peninsula, south of St. Lawrence Island and north Bristol Bay (Dickson et al. 1999).

King Eiders winter in polynyas in the Bering Sea: most notably the one off the southeast coast of Chukotsk Peninsula, but also polynyas associated with offshore islands such as St. Matthew Island (Kistchinski 1973, USFWS 1999, Dickson et al. 1999). They also winter off the Aleutian Islands and Alaska Peninsula, south to Kodiak Archipelago, and off Kamchatka Peninsula.

Counts of King Eiders flying past Point Barrow, Alaska during spring migration indicate the population that nests in northern Alaska and western arctic Canada declined by over 50 percent between 1976 and 1996 (Suydam et al. 2000). Aerial surveys for breeding populations conducted for three years in the early 1990s in the western Canadian Arctic also suggest a substantial decline since 1960 (Dickson et al. 1997). In northern Alaska, two different sets of aerial surveys for breeding populations both indicate a stable population during the 1990s (King and Brackney 1997, Larned and Balogh 1997).

Spectacled Eider

Spectacled eiders (*Somateria fischeri*) are large diving sea ducks that spend most of the year in marine waters, where they primarily feed on bottom-dwelling mollusks and crustaceans. Besides breeding and molting in some Alaska coastal areas, spectacled eiders congregate during the winter in exceedingly large and dense flocks in polynyas in the pack ice in the central Bering Sea between Saint Lawrence and Saint Matthew Islands. Spectacled eiders from all three known breeding areas (in Alaska and Russia) use this wintering area. While at sea, spectacled eiders appear to be primarily bottom feeders, eating mollusks and crustaceans at depths of

up to 70 m in the wintering area (USFWS 1999a). Because nearly all individuals of this species may spend each winter occupying an area of ocean less than 50 km (31 mi) in diameter, they may be particularly vulnerable to chance events during this time (USFWS 2000a).

Based on nest surveys, about 8,000 birds (4,000 pairs) breed on the Yukon-Kuskokwim Delta (Bowman et al. 1999). Current minimum breeding populations (uncorrected for detection) are 7,000 birds along the North slope (Larned et al. 1999) and 146,000 birds in arctic Russia (estimated during a one-time aerial survey from 1992-1994).

The North American Waterfowl Breeding Pairs Survey and other more recent surveys indicate that numbers of spectacled eiders breeding on the Yukon-Kuskokwim Delta dropped by about 94 percent from about 48,000 pairs in the 1970s to less than 5,000 by 1992 (Ely et al. 1994, Stehn et al. 1993). Surveys suggest the Yukon-Kuskokwim Delta population now stands at about 8,000 birds and has stabilized or increased slightly from 1992–1999 (Bowman et al. 1999, Eldridge et al. 1999). Surveys on the North Slope of Alaska suggest a fairly stable trend from 1993–1999 (Larned et al. 1999). Nothing is known about spectacled eider population trends in Russia due to the lack of systematic surveys.

Steller's Eider

Steller's eider (*Polysticta stelleri*) are medium-sized seaducks that inhabit nearshore marine waters, where they feed by diving and dabbling for mollusks and crustaceans. Primary foods in marine areas include bivalves, crustaceans, polychaete worms, and mollusks (USFWS 1997b). A diet study of Steller's eiders conducted in Nelson Lagoon from April to October in 1977 and 1979 indicated that bivalves and amphipods were the primary food items, specifically blue mussels (*Mytilus edulis*), clams (*Macoma balthica*), and gammarid amphipods (Petersen 1981). Three breeding populations of Steller's eiders are recognized, two in arctic Russia and one in Alaska. Actual numbers nesting in Alaska and Russia are unknown, but the majority of Steller's eiders nest in arctic Russia (USFWS 1997b). After the nesting season, Steller's eiders return to marine habitats, where they molt. Concentrations of molting Steller's eiders have been noted in Russia, near Saint Lawrence Island in the Bering Sea, and along the northern shore of the Alaska Peninsula.

There are two geographical populations of Steller's eiders, separated by their breeding and winter distribution. The Atlantic population breeds in western Siberia (Solovieva 1997) and winters in the Barents and Baltic seas (Nygard et al. 1995). Most of the Pacific population inhabits the maritime tundra of northeast Siberia (Solovieva 1997), and a smaller population nests in Alaska on the Yukon-Kuskokwim Delta (Flint and Herzog 1999) and the Arctic Coastal Plain (USFWS 1999). The Pacific population winters primarily in Alaska in the Bering Sea (Palmer 1976).

Aerial surveys of principal nesting areas in arctic Russia during 1993–1995 indicated a minimum of 149,000 (USFWS 1999). In North America, aerial surveys of the Arctic Coastal Plain of Alaska breeding habitats averaged 4,800 pairs from 1990–1998 (USFWS 1999), and on the Yukon-Kuskokwim Delta in western Alaska they currently breed in low numbers (Flint and Herzog 1999) where, historically they may have nested in greater densities (Kertell 1991). However, there are no reliable estimates of breeding numbers for the Yukon-Kuskokwim Delta.

Molting and wintering populations of Steller's eiders along the Alaska Peninsula have declined since the 1960s (Jones 1965, Kertell 1991, USFWS 1999). There is no trend data for other Pacific wintering populations. Coincident with declines in wintering populations, there is evidence of reductions in densities of breeding birds on the Yukon-Kuskokwim Delta and the Arctic Coastal Plain of Alaska (Kertell 1991, Flint and Herzog 1999). In Siberia, the species is now considered rare, although replicate aerial surveys of breeding habitats are limited to three years, 1993–1995 (USFWS 1999).

3.5.2 Factors that Influence the Availability of Food to Seabirds

Successful foraging by seabirds depends on adequate stocks of prey; foraging also is limited by conditions that make prey available to the birds. The nonrandom distribution of birds at sea shows a correspondence to upwellings, surface convergences, currents, or other physical processes and factors that influence productivity (Woodby 1984). All seabirds depend on specific oceanographic processes to concentrate their prey at the necessary place, time, and position in the water column (review in Hunt et al. 1999). A growing body of evidence indicates that in partitioning prey resources, seabirds utilize different marine habitats for foraging (Croxall and Prince 1980, Harrison et al. 1983, Weimerskirch et al. 1988, Weimerskirch 1998, Hunt et al. 1998).

Data concerning factors that limit seabird prey availability for some species groups and for many areas of Alaska are lacking. Winter information is also needed for almost all species. Most critical is the lack of information on how events beyond a seabird's foraging range may influence the prey availability. Such factors may include environmental changes, fluctuations in regionwide stocks of forage and non-forage species, and commercial harvests.

Factors that limit the food availability to seabirds have been investigated primarily during the past ten years, and directed research is recent. Intensive work has taken place in the southeastern Bering Sea (short-tailed shearwaters, kittiwakes, and murre [Springer et al. 1986, Schneider et al. 1990, Hunt et al. 1981, Coyle et al. 1992, Decker et al. 1995, Decker and Hunt 1996]); northern Bering and Chukchi Seas (murre, kittiwakes, and auklets [Springer et al. 1987, Elphick and Hunt 1993, Kinder et al. 1983]); the western Aleutian Islands (auklet [Hunt et al. 1993, Hunt et al. 1998, Russell et al. 1999]); and Cook Inlet and PWS (murre, kittiwakes, pigeon guillemots, and tufted puffins [Kuletz 1983, Hayes and Kuletz 1997, Ostrand et al. 1998, Piatt et al. 1998, Suryan et al. 1998a, Suryan et al. 1998b, Golet et al. 2000, Suryan et al. 2000, Piatt et al. 1997]). In each place, only part of the factors affecting bird forage availability have been explored. All studies were restricted to summer. Limiting factors in areas that have not yet been studied are likely to differ in type and importance, and they may be completely different in winter when forage species and locations are different. Winter diets for common murre and marbled murrelets in Kachemak Bay, Alaska, were recorded by Sanger (1987b). Albatrosses have not been directly studied in the BSAI or GOA. Some diet information is available on the Laysan's and black-footed from the central North Pacific (Gould et al. 1998), diet information from albatross colonies in the northwestern Hawaiian Islands is available (Harrison et al. 1983) and recent satellite telemetry studies have noted breeding Laysan's albatrosses foraging in the Bering Sea (Anderson et al. 2000). Conversely, albatrosses have been studied extensively in the Southern Hemisphere, where more procellariid species occur. The food and foraging ecologies of Southern Hemisphere albatrosses are much better known (Croxall and Prince 1980, Weimerskirch et al. 1985, Weimerskirch et al. 2000, Waugh et al. 1999a and 1999b, Weimerskirch et al. 1988, Croxall and Prince 1996, Cherel and Weimerskirch 1995), and the potential impacts of fisheries on albatross populations have been noted, with the most serious concern being that of albatross mortality from longline fisheries (Brothers et al. 1998, Weimerskirch and Jouventin 1987, Croxall et al. 1990, Brothers 1991, De la Mare and Kerry 1994, Robertson and Gales 1998). Other impacts, such as competition for prey (squid and fish) and fisheries providing additional food resources, are also discussed (Gremillet et al. 2000, Reid et al. 1996).

3.5.2.1 Oceanographic Factors

Subarctic gyres (permanent ocean currents that move in a circular direction) are prominent oceanographic features that provide linkage and exchange between subtropical and transitional waters of the North Pacific Ocean and arctic waters of the Bering Sea and Sea of Okhotsk (Springer et al. 1999). Although coastal and shelf production is much higher during summer, the pelagic areas encompassed by gyres form an important wintering and nursery area for many species of birds and marine mammals that breed onshore around the

perimeters. The Eastern Subarctic Gyre is formed by the North Pacific Current on the southern boundary and by the Alaska Current, which forms the gyre's eastward and poleward boundaries. The Alaska Current is broad on the eastern side of the GOA (300 km), but narrows to about 100 km in the western GOA and is the only significant current contributing to the flow around the Eastern Subarctic Gyre (Reed and Schumacher 1986). In contrast, circulation in and around the Western Subarctic Gyre is much more complex, with contributions from three major current systems that originate in distinct oceanographic settings. Seabird biomass in the subarctic North Pacific Ocean is concentrated over the shelf and slope near the continents in all seasons, with the densities in the open ocean very small by comparison (Springer et al. 1999). Additionally, the densities are higher in the western subarctic than in the eastern subarctic, and the contrast is particularly noticeable in the centers of the gyres. The increased complexity of the physical oceanographic environment and more intense circulation in the western subarctic is probably what accounts for its higher primary and secondary production. Whereas seabirds are distributed more evenly across the Western Subarctic Gyre, the abundance of several species appears to be greatly reduced in the center of the Eastern Subarctic Gyre. This distribution probably results from the physical process and patterns of food web development, which lead to higher prey abundances at the margins (Springer et al. 1999).

Physical characteristics of the water column and ice cover concentrate seabird prey. Depending on size, shape, and foraging method (surface-feeding or diving, nearshore or offshore), bird species differ in their requirements and preferred habitats (summarized in Section 3.5.1). Oceanographic phenomena that influence seabird foraging habitat primarily are on the scale of hundreds of meters to hundreds of kilometers (Hunt and Schneider 1987). Favorable foraging conditions are likely to last for a relatively short time (hours to weeks) at one spot and for many Northern Hemisphere seabirds foraging in shelf waters, small-scale physical processes that concentrate prey are very important for successful foraging (Hunt et al. 1999). Different combinations of factors limit the availability of prey for different seabird species. Factors also differ among areas of Alaska (Byrd et al. 1997).

Fronts and upwellings are important in concentrating seabird prey. The inner front (boundary between wind-mixed and stratified water on the Bering Sea shelf) is associated with an upwelling 5 to 15 km in width, which tends to concentrate some zooplankton and their predators (Schneider et al. 1987, Brodeur et al. 1997). This region is primarily exploited by diving seabirds, particularly the short-tailed shearwater (a plankton feeder) and murre (a fish feeder) (Decker and Hunt 1996, Hunt et al. 1996c). Availability of prey to these seabirds may vary with strength of the upwelling (Schneider et al. 1987). The outer front and shelf edge, where water from the continental slope is upwelled, is important to thick-billed murres and several surface-feeding seabird species, including northern fulmars, shearwaters, and kittiwakes. Some of the state's largest seabird colonies are located within foraging range of the shelf edge, including Saint George Island, several Aleutian Islands, and the Semidi Islands (western GOA).

Upwellings also occur where tides or currents move water from the deep ocean onto the shelf, such as tidal upwellings onto the shelf between islands in the Pribilof Islands (Coyle et al. 1992) and the Aleutian Islands (Hunt et al. 1998), or the Anadyr Current west of Saint Lawrence Island (Hunt et al. 1990). Auklets nest abundantly in these areas because upwellings bring oceanic zooplankton to shallow waters nearby (Springer and Roseman 1985; Hunt et al. 1993). Upwelling of deep water onto the shelf north of the Barren Islands and in the western GOA supports large colonies of murres, kittiwakes, and puffins (Piatt and Anderson 1996). At the Pribilof Islands, the currents that influence prey availability are mostly tidal, though zooplankton are advected from offshore (Hunt et al. 1996d, Stabenho et al. 1999). Currents that run parallel to the shelf break along the 100-m and 200-m isobaths, and which spawn eddies that cross onto the shelf, are likely to be most important (Stabenho and van Meurs 1999). These currents may also be important for the transport of age-0 pollock to the Pribilofs, suggesting that pollock spawning events near Unimak Pass may influence prey availability at the Pribilofs (G. L. Hunt, Jr., University of California, Irvine – personal communication). The influence of upwellings and fronts on seabird populations, and the effect of changes in these processes, have

not been studied in most areas. Eddies may be important in attracting and concentrating seabird prey in the vicinity of islands, headlands, and seamounts (Hunt and Schneider 1987).

Stratification of the water column is important in prey availability to seabirds. Small forage species, such as zooplankton, concentrated at pycnoclines and thermoclines are available to shallow-diving seabirds such as least auklets (Haney 1991, Hunt et al. 1990, Hunt et al. 1999). Prey availability for these birds depends on the presence of suitable stratification near breeding colonies (Hunt 1990). Location of prey concentration vertically within the water column, due to a pycnocline, may vary from days to months, depending on the strength of mixing events (Hunt et al. 1999). Stratification can be disadvantageous to species that depend on complete mixing of the water column. In summer, lack of wind and strong solar heating can result in higher surface temperatures, which may in turn cause certain prey species to seek deeper water and be unavailable to such surface-feeding birds as terns and kittiwakes (Baird 1990). Lack of mixing can also weaken upwelling at the inner front where short-tailed shearwaters feed (Section 3.5.2.1). The influence of stratification on seabird foraging in most specific areas is unknown.

Currents vary in strength from one year to another, but their influence on seabird prey is known only for a few areas. Principal seabird prey in these areas may be carried there by currents from a long distance. Currents are important for the availability of prey to auklets in the northern Bering Sea, in the Chukchi Sea (see review in Hunt 1997), and at the Pribilof Islands (Hunt et al. 1996c). Tidal currents at the Pribilofs are also important in determining the availability of euphausiids to murre (Coyle et al. 1992). The Alaska Coastal Current in the northern Bering and Chukchi seas originates, in part, from discharge of the Yukon River (Springer et al. 1984), but it may also be influenced by river flows as far away as the GOA (Piatt and Anderson 1996). The coastal current in the western GOA sweeps immature pollock from spawning grounds near Kodiak Island to the vicinity of seabird colonies on the lower Alaska Peninsula (Hatch and Sanger 1992, Byrd et al. 1997, Wilson 1997). In northwestern Alaska, small schooling fish such as Pacific sand lance are available during the seabird chick-rearing periods if a large warm plume of water reaches that coast in early to mid-July (Springer et al. 1984). Tidal currents at the Pribilofs are also important in determining the availability of euphausiids to murre (Coyle et al. 1992). The influence of currents on seabird foraging in most specific areas of the North Pacific, including colonies near the shelf edge, is unknown.

The edge of the ice pack and polynyas within it provide important winter and spring habitat for large gulls, guillemots, murre, and other seabirds that forage on zooplankton and fish of the ice-edge system (Hunt 1991, Hunt et al. 1996d). Recently, the winter location of the threatened spectacled eider was found in pack ice openings south of Saint Lawrence Island (Petersen et al. 1999), indicating of the potential importance of this habitat outside the breeding season.

Temperature of marine waters is another factor that influences prey availability. Years with warm coastal currents are associated with high Pacific sand lance abundance and increased breeding success for black-legged kittiwakes in Norton Sound and the Chukchi Sea (Springer et al. 1984, Springer et al. 1987). Sea surface temperature also influences availability of forage to seabirds, irrespective of fish abundance; cold sea surface temperatures are associated with high kittiwake breeding success in the Pribilof Islands (Springer and Byrd 1989). This occurs possibly because warmer surface waters are stratified, and forage fish remain too deep for kittiwakes to obtain them. Temperature may influence forage fish availability for seabirds in many other ways, from local effects to large-scale stock trends, but nothing is known of these factors.

Section 3.5.1.12 describes numerous studies highlighting the foraging ecology of auklets and relationships to physical oceanographic processes. In addition, Section 3.5.1.4 discusses die-offs of shearwaters and how this relates to oceanographic anomalies.

Regime shifts appear to influence the abundance and distribution of seabirds. Effects of regime shifts on Alaskan seabird populations can only be surmised for the past 20 years, when data on most seabird populations are available, which is a shorter period than that of some potential regimes. Water temperature and associated water-mass characteristics influence the productivity, abundance, and distribution (both vertical and horizontal) of seabird prey in both the short and long term (Section 3.5.2). The availability of high-value forage species such as capelin and Pacific sand lance declined sharply when the regime shifted during the late 1970s and has not yet returned to former levels. The result has been declines in the breeding success and populations of piscivorous (fish-eating) species in several areas of Alaska (Springer 1992, National Research Council 1996, Piatt and Anderson 1996, Kuletz et al. 1997, Francis et al. 1998, McGowan et al. 1998, Anderson and Piatt 1999, Agler et al. 1999).

Numerous studies have demonstrated that seabirds reflect the distribution and abundance of prey through their foraging ecology (Decker et al. 1995). Additionally, seabird dietary changes reflect prey availability and have been related to the collapse of commercial fisheries stocks (Montevecchi et al. 1988). Thus, seabirds may indicate fluctuations in fish populations brought on by environmental perturbations, such as climate change or commercial harvesting (Decker et al. 1995). Between 1975 and 1990, seabird reproductive performance at the Pribilof Islands fluctuated widely (Springer 1992). Major shifts in seabird food habits occurred at the Pribilof Islands between the mid-1970s and the late 1980s. These diet shifts coincided with the decline of murre and kittiwake populations there, and with the decline of forage fishes and age 1 pollock in the bottom trawl surveys around the Pribilof Islands (Decker et al. 1995, Hunt et al. 1996d, Hunt et al. 1996c). It seems very likely that the decline in the abundance of age 1 pollock around the islands had an impact on those populations (G.L. Hunt, Jr. University of California, Irvine – personal communication). Seabird reproductive performance and diets did not return to pre-1979 values after 1984, suggesting that the marine ecosystem changes the birds responded to were longer than the periods of warm and cool surface temperatures observed between 1975 and 1990 (Decker et al. 1995).

Likewise, several species of seabirds nesting in the GOA experienced a decrease in breeding success and abundance in the mid-1970s that coincided with diet shifts, indicating changes in prey populations (Piatt and Anderson 1996). A shift in climate regime at this time triggered a reorganization of trophic structure in the GOA ecosystem and apparently occurred at the expense of both piscivorous marine birds and mammals (Anderson and Piatt 1999).

Longer climatic cycles have changed seabird communities in ways that can only be inferred from the fossil record (Duffy 1993, Warham 1996). Studies of sea surface temperature anomalies in the northwest Atlantic from the 1870s to the 1990s indicate a general long-term warming trend, which implies interactive and synergistic effects on fish distributions and populations, and hence on seabird feeding ecology and reproductive success. Such changes might be initially detected near the limits of seabird ranges and the margins of oceanographic regions (Montevecchi and Myers 1997). Effects of a given regime shift on seabirds, as for other environmental variables, can be expected to differ among species and among regions of the state.

3.5.2.2 Ecological Interactions Affecting Seabirds

Various ecological factors may determine whether valuable forage species are present within a bird's feeding range, and whether prey are available to the birds. Even where some information exists on forage species and areas that are important to seabirds, there usually is no information on the small age classes of fish (5 to 15 cm) consumed by birds.

Habitat requirements of forage species may limit whether a species is present within seabird foraging range. Of the high-value forage species of seabirds, only one or two are typically available to seabirds in a given area

(Springer 1991b): Pacific sand lance in most of the Bering Sea (Springer 1991b, Springer et al. 1996); pollock and formerly capelin in the Pribilof Islands (Hunt et al. 1981a, Springer 1991b, Roseaneau et al. 1988, Decker 1995); capelin and pollock around the Alaska Peninsula (Springer 1991b, Hatch and Sanger 1992); and capelin, Pacific sand lance, herring, and pollock in the northern GOA (Hatch and Sanger 1992, Piatt et al. 1998, Suryan et al. 1998b, Suryan et al. 2000, Golet et al. 2000). The availability of forage species often varies within small areas, such as Prince William Sound, Cook Inlet, and island groups in the Aleutian Islands (Byrd et al. 1997, Piatt et al. 1998, Suryan et al. 1998b). The preferred forage species in each area usually is essential for successful seabird reproduction (Springer et al. 1986, Springer et al. 1987, Baird 1990, Piatt and Anderson 1996, Golet 1998, Golet et al. 2000, Piatt et al. 1998, Suryan et al. 1998a, Suryan et al. 1998b, Suryan et al. 2000).

At the Pribilof Islands, there has been a shift from capelin to Pacific sand lance as the fatty forage fish available to diurnal seabirds (Decker et al. 1995), as well as a decline in the use and abundance of age 1 pollock (Hunt et al. 1996e). In an analysis of seabird diet changes, Hunt et al. (1996d) suggested that the decline in the use of fatty fishes, including myctophids, was correlated with reduced reproductive success. However, when pollock dropped significantly in diets and kittiwakes were forced to rely primarily on fatty forage fishes, which may have been scarce, reproductive success also diminished. It appears, then, that either because the Pribilof colonies are so large, or because fatty forage fishes are generally scarce, an abundant supply of pollock, preferably age 1 pollock, is important there.

Habitat requirements of seabird forage species are poorly known, particularly for the size classes consumed by birds (6 to 15 cm for most bird species) and for the specific areas that are important to foraging seabirds. The information that exists is best for the species whose adults are seabirds prey, such as capelin and Pacific sand lance, and for juvenile pollock. Habitats of other important forage groups, such as myctophids and juvenile herring, are poorly known. Recent studies, however, have provided data on the seasonal patterns and habitat for several forage fish species in Cook Inlet (Robards et al. 1999, Blackburn and Anderson 1997) and for juvenile herring (Brown et al. 1999, Paul and Paul 1999) and juvenile pollock (Paul et al. 1998) in PWS.

Forage species stock sizes and productivity are among the factors that determine the abundance and availability of these species in seabird foraging areas. Seabirds must have access to prey within efficient foraging range of the breeding colony in order to successfully raise their chicks (Piatt and Roseaneau 1998, Suryan et al. 1998a, Suryan et al. 2000, Golet et al. 2000). For example, breeding success of black-legged kittiwakes in Cook Inlet varied with local stocks of capelin (Piatt et al. 1998). In Prince William Sound, success of black-legged kittiwakes (Suryan, unpubl. data), pigeon guillemots (Golet et al. 2000), and marbled murrelets (Kuletz unpubl. data) correlated with years and sites of relative abundance of forage species. For most seabird species or areas, information is rarely available on the relationship between forage stocks and breeding success. In other regions, however, there is considerable circumstantial evidence of links between depletion of forage fish stocks and subsequent declines in seabird populations (Furness 1982 and 1984).

Mere presence of forage species in a bird's feeding range is not the sole factor in seabird food supply. Schools or swarms of forage fish must be of sufficient size and density for seabirds to exploit them efficiently (Hunt et al. 1990, Piatt and Roseaneau 1998). Schools also must be available in the respective habitat for each seabird species (Hunt and Harrison 1990, Ostrand et al. 1998), including at a depth which the seabird can reach (Section 3.5.1). No information exists on the influence of stock size on the availability of forage schools to seabirds.

Stocks of many forage fish species may change with overall abundance. Seabird colonies near the edge of a forage species' range may experience large fluctuations in food supply with changes in an overall forage stock, while food may be more reliable at colonies near the core of the forage species' range (MacCall 1984). Changes in overall fish stocks, due to either fishery pressures or environmental changes, may therefore affect

the local availability of forage to seabirds. Any effects of stock changes on seabirds almost certainly will vary among areas. Although data on the relationship between stock sizes and availability to seabirds are lacking for most specific areas, improvements in hydroacoustic methods have increased our knowledge of these patterns (Hunt et al. 1999). The relationship between prey availability and density is complicated by different seabird distribution patterns relative to their prey. When prey are at the surface, seabird aggregations may be tightly coupled with prey, but if prey are deep, there is little correspondence beyond a coarse scale (Hunt et al. 1999). Several studies indicate that when prey abundance is above a certain threshold, birds will no longer track prey closely, but in years with low prey abundance, birds will be tightly associated with prey patches (Hunt et al. 1999). Three distinct levels of patchiness in the spatial relationship between murre and capelin in the Barents Sea have been observed, with associations focused at more than 300 km, approximately 50 km, and approximately 3 km. (Fauchald et al. 2000).

Movements and schooling behavior of forage fish species often determine whether the species will be available at a place and time suitable for seabird foraging. Densities of foraging seabirds are often correlated with prey densities (Hunt 1990, Hunt et al. 1999, Fauchald et al. 2000). Currents disperse some small forage species, but other species contribute to their own locomotion. Diurnal vertical migrations by pelagic plankton, myctophids, and squid determine their availability to surface-feeding birds such as northern fulmars and kittiwakes (Hatch 1993, Hatch et al. 1993). Pacific sand lance, juvenile herring, and other forage species are available to birds at times when they form dense schools in shallow water; these fish may be dispersed too greatly at other times for efficient foraging by many seabird species (Hunt et al. 1990, Blackburn and Anderson 1997, Piatt and Rose 1998, Irons 1998). Breeding success and population trends of kittiwakes in the northern Bering Sea and of pigeon guillemots in Prince William Sound are correlated with years when schools of Pacific sand lance are available (Springer et al. 1987, Hayes and Kuletz 1997). Schools must be at or near the surface in order for kittiwakes and terns to reach them; these birds are usually observed feeding on shoals of Pacific sand lance in years when reproductive success is high (Baird 1990).

Competition and predation may influence seabird prey availability. Links between seabirds and other species could be direct, or they could be extremely diffuse and indirect. Possible links include competition between seabird species; competition of piscivorous seabirds with other large marine predators such as marine mammals and fish; cannibalism by large pollock on the smaller pollock preyed on by some seabirds; competition for food among forage species, such as small pollock, capelin, Pacific sand lance, herring, myctophids, and squid; competition between planktivorous seabirds with whales or planktivorous fish (including forage fish of other seabird species); and even ecosystem links with groups such as jellyfish. Little information is available on the magnitude or direction of these links.

The energy content of prey has recently been found to influence the growth of seabird chicks and reproductive success at the colony level (Kitaysky 1999, Kitaysky et al. 1999, Golet et al. 2000). Fish with high lipid and low water content provide the most efficient food "package" for growing seabird chicks; such fish include myctophid, capelin, Pacific sand lance, and larger age groups of herring. Energy-poor forage species include pollock and benthic fish. Young black-legged kittiwakes and tufted puffins fed high-value fish grow faster than those fed pollock (Romano et al. 1998). Slow-growing young birds in colonies may ultimately starve in the nest or be more vulnerable to post-fledgling stresses than well-fed young. Growth rates, reproductive success, and population trends of several seabird species are correlated with availability of high-value prey in the northern GOA (Anthony and Roby 1997, Golet 1998, Piatt et al. 1998, Roby et al. 1998, Golet et al. 2000, Suryan et al. 2000).

The influence of prey energy content on seabird trends in other parts of Alaska has not been investigated. For instance, kittiwakes and murre, which often consume pollock in the Pribilof Islands, where capelin and Pacific sand lance are less available (Hunt et al. 1981b, Schneider and Hunt 1984), are able to raise chicks. However, kittiwake breeding success is relatively low in these colonies compared with other parts of Alaska (Hatch et

al. 1993b), and murre and kittiwake populations have recently declined on the Pribilof Islands (Section 3.5.1). The relative value of prey species to breeding seabirds may vary among areas, depending on factors such as distance to foraging areas and body composition of forage species. The relative value of pollock and other prey to seabird populations in the Pribilof Islands is unknown.

The fraction of total exploitable stocks in the eastern Bering Sea that are consumed by seabirds have been estimated at 3 percent for pollock and less than 1 percent for herring (Livingston 1993), which is similar to an estimate of 4 percent for Pacific sand lance in the North Sea (Furness and Tasker 1997). Seabirds, therefore, may account for a very minor proportion of forage fish mortality, even for the young age classes that they consume (Livingston 1993). Seabirds may have greater impacts on fish stocks within foraging range of seabird colonies, however, because the birds are concentrated there during summer (Springer 1986, Roseman et al. 1988, Birt et al. 1987). Fifteen to eighty percent of the biomass of juvenile forage fish may be removed by birds near breeding colonies each year (Wiens and Scott 1975, Furness 1978, Springer et al. 1986, Logerwell and Hargreaves 1997). This suggests that food availability to birds may be limited, at least in a given season, by the size of the local component of fish stocks. Seabirds may, therefore, be vulnerable to factors that reduce forage fish stocks in the vicinity of colonies (Monaghan et al. 1994). The availability of forage fish to seabirds also would depend on the rate of fish immigration and on factors that limit the ability of birds to capture the fish present in the area (Section 3.5.2).

Estimates of seabird predation pressure on forage stocks are based on incomplete data. Existing information on seabird diet, consumption, and energetics has been obtained during the breeding season. Broad assumptions must, therefore, be made for the other nine months of the year, and for the nonbreeding component of populations (roughly 15 to 50 percent of the total) throughout the year. Diets and factors that limit prey availability during nonbreeding periods are presumably different from those in summer. Some authors believe that food is more limited in winter than summer for many species (Croxall 1987). Outside the breeding season, diets, feeding habitats, energy requirements, and distribution have been studied only minimally for most seabird species. Limited information suggests that in winter months many seabirds consume a greater variety of fish as well as higher proportions of zooplankton and invertebrates (Sanger 1986 and 1987b). Predation pressure of birds on forage fish stocks is unknown for most stocks and areas. The proportion of noncommercial forage fish species taken by seabirds cannot usually be estimated because no information exists on stock sizes for these species. Recent studies in Glacier Bay, Cook Inlet, and Prince William Sound, however, which obtained estimates of forage fish biomass, will provide information in the near future.

Regionwide conditions that may influence local prey availability are not well described, but are being investigated by GLOBEC. Climate and food-web changes can occur over the entire Bering Sea or GOA, and several reviews indicate that such large-scale fluctuations affect prey availability for seabirds (Anderson and Piatt 1999, Francis et al. 1998, McGowan et al. 1998, Agler et al. 1999). The mechanisms of how oceanographic changes alter marine communities require further investigation.

3.5.3 Seabird Responses to Changes in Forage Availability

The availability of food resources to seabirds depends not only on forage fish species and their physical environment, but also on the response of each bird species to prey availability. Seabird species differ in their foraging adaptations, ways in which they respond to change, relationships with competitors, and the effects on populations of changes in their food supply.

The response of several seabird species to changing forage conditions has been studied in some detail. For many species, however, flexibility and behavioral limitations are known only in general. The effects on populations of changes in the food supply, and the minimum abundance of forage that each species requires, have been studied for only a few species in the northern GOA. Information is needed on limiting prey densities

for most Alaskan species (the prey densities at which breeding success is insufficient to maintain populations). Studies are needed of all species in several areas of Alaska; limiting densities of prey are likely to differ among regions, depending on which prey birds depend on, prey availability, and whether alternative prey are available. More specific data on minimum biomass required for reproductive success in seabirds may soon become available for parts of the northern GOA as Exxon Valdez Trustee Council studies are concluded.

3.5.3.1 Foraging Behavior and Flexibility

Foraging behavior and flexibility limit each species' responses to changing conditions. In general, seabird diets consist of fish or squid 5–15 cm long or large zooplankton. Diets and foraging ranges are most restricted during the breeding season, when high-energy food must be delivered efficiently to nestlings. Foraging adaptations and habitat selection for each bird species are described in Section 3.5.1. Species-specific adaptations include foraging range from breeding colonies, depth at which prey can be obtained, prey size and type, optimal and limiting densities of prey aggregations, and ability to switch to foods such as other fish species, invertebrates, detritus, or terrestrial organisms. Seabirds learn where to find aggregations of their prey under various conditions, and they may return to favorable areas regularly (Hunt et al. 1999).

Albatrosses are unique among seabirds in that they display the largest foraging areas so far recorded in any extant central-place forager (Gremillet et al. 2000). During the breeding season, wandering albatrosses (*Diomedea exulans*), for example, may travel 15,000 km over the Southern Ocean during a single feeding trip. This performance is made possible by dynamic soaring, a flight technique that enables these birds to travel at low-energy cost for extended periods (Pennycuik 1989). Satellite tagging is being used to identify the vast foraging areas for many albatross species in the Southern Ocean.

Seabirds differ from one another in their ability to respond to changing conditions. For instance, most surface-feeding species can forage over greater distances than diving birds (Shuntov 1993), but diving birds can exploit prey at greater depths than surface feeders (Baird 1990, Monaghan 1996). Murres can forage deeper than any other species, which buffers them against changes in vertical distribution of their prey; however, their need for dense aggregations of prey may make them vulnerable to occasional die-offs when prey are scattered or otherwise unavailable (Piatt and van Pelt 1997). Murres can increase the daily foraging time needed in order to obtain scarce or distant prey, and they sometimes are able to maintain breeding success under poor conditions; in contrast, seabirds such as terns and kittiwakes often do not have the extra time available each day to make this adjustment (Monaghan et al. 1992, Furness and Tasker 1997, Piatt et al. 1998). However, within Prince William Sound, differences can occur among kittiwake colonies in foraging range, trip duration and feeding rate, consistent with fish availability, suggesting some buffering capabilities (Suryan et al. 2000). Pigeon guillemots can forage either on schooling energy-rich fish or on dispersed, energy-poor benthic fish, but breeding success and population stability are supported best by schooling fish (Kuletz 1983, Golet et al. 2000). Gulls can switch to invertebrate prey or scavenging when schooling fish decline, but breeding success suffers (Murphy et al. 1984). Foraging adaptations of seabirds may differ among areas according to prey aggregation size, alternative prey availability, distance to foraging areas, depth of the prey, and many other factors.

3.5.3.2 Seabird Interactions with Each Other and with Marine Mammals

Seabird interactions with each other and with marine mammals influence their populations (Mehlum et al. 1998, review in Hunt et al. 1999). Seabirds compete within and between species for food and nesting space. The influence of such competition on populations is largely unknown, although evidence has been presented that large Alaskan colonies may be limited by competition for food (Hunt et al. 1986). Seabirds that feed in flocks may benefit by interactions within and among other species; surface-feeding birds may attract others to prey aggregations, while diving birds appear to drive subsurface prey within reach of surface-feeders (Hoffman

et al. 1981, Hatch 1993, Maniscalco et al. 1998, Ostrand 1999). Bottom-feeding marine mammals such as gray whales also increase the availability of prey and detritus to surface-feeding birds (Harrison 1979, Hunt 1990, Obst and Hunt 1990).

3.5.3.3 Population Responses of Seabirds to Changes in Forage Availability

Trends in seabird populations are the result of forage availability and food-web changes. Depending on individual foraging success, the population of each species may maintain itself, increase, or decline. Population trends may last for a few years or many decades, and they may be local or cover large regions, depending on fluctuations in forage availability. Trends are likely to differ among seabird species in the same area and time period, because forage availability will vary with a seabird's body size and feeding behaviors (Chastel et al. 1995, Putz et al. 1998).

The responses of seabird populations to prey abundance have been examined theoretically, and forage and population trend relationships have been studied for a few species in the field. When forage is below some minimum level of availability, birds cannot raise enough young to replace those that die, and (in extreme cases) adult birds may even die from starvation. One or two bad years will not cause a population decline, but if food remains scarce, the population decreases. Cairns (1990) theorized that seabird productivity and populations show sigmoidal threshold responses to prey abundance. He suggested that, at intermediate forage levels, breeding is increasingly successful; populations are stable or fluctuate only slightly. At some higher level of forage availability, birds are able to raise the maximum number of young (roughly 0.5 to 3 young per breeding pair per year, depending on the species), and the population increases. Additional forage above this upper threshold will not increase breeding success or population growth further due to other density-independent factors.

The relationships between forage abundance and seabird population trends differ among species. Some species can maintain themselves while foraging on relatively low prey densities; others in the same area require much higher densities. Examples include puffins exploiting lower densities of capelin than murres in Newfoundland (Piatt 1990). Preliminary data that suggests that murres may be able to subsist on lower densities of Pacific sand lance in Cook Inlet than kittiwakes (Piatt et al. 1998). Highly dispersed, noncolonial birds such as marbled murrelets may be particularly well adapted to patchy, highly dispersed prey in low-density schools (Ostrand et al. 1998, Kuletz 1999).

Field studies and modeling work on the relationships of seabird populations to local prey densities are only beginning. Much more information is needed on limiting prey densities for most Alaskan species. Prey densities, per se, are not the limiting factor experienced by birds, but rather densities of available prey. Limiting densities for many bird species may vary among regions of the state, depending on factors such as the principal and alternative prey species.

3.5.4 Incidental Seabirds Catch in Fishing Gear

Seabirds are caught incidentally in all types of fishing operations (Jones and DeGange 1988). In a coastal drift gillnet fishery in Washington State, sea state and time of day were significant predictors of seabird incidental catch rates, indicating that visibility or maneuverability, as well as feeding behavior, may affect susceptibility of birds (Melvin et al. 1999). In groundfish fisheries, longlines account for most seabird incidental catch. Trawls also take some seabirds, primarily those that feed beneath the surface on prey in the water column. Pots occasionally take diving seabirds. Some birds also are injured or killed by striking the vessel superstructure or gear while in flight.

Monitoring Seabird Incidental Catch and Seabird and Fishery Interactions

Data collection regarding seabird and fishery interactions by NMFS in the groundfish fisheries began in 1990 and was expanded during the 1993, 1997, 1999, and 2000 seasons. The collection of seabird incidental catch data was integrated into an existing comprehensive data-gathering observer program designed to collect data for a wide variety of management and research purposes. Data include total catch and effort, catch composition, prohibited species bycatch, and other biological information. The major change, in 1993, was to have observers provide genus or species identifications of incidentally caught seabirds. During species composition sampling, the observer makes a reliable identification (to species or species group) and records the numbers and weights of birds in the sample. NMFS uses these incidental mortality data by seabird species to calculate incidental catch rates of the observed hauls and to extrapolate numbers of seabirds incidentally caught from the observed portion of the fleet to the unobserved portion, resulting in an estimate of total seabird incidental catch. Other observer-collected information, which NMFS forwards to USFWS, is sightings of sensitive species (six species of special concern whose populations are very small or declining), any bird and vessel interactions, documented collisions of birds with the vessel superstructure, and detailed information found on the leg bands of banded seabirds. NMFS coordinated with the USFWS to update the seabird section of the NMFS observer manual. This included the incorporation of a standardized USFWS form for reporting sightings of sensitive species. This same USFWS form is available to fishermen to report sightings of short-tailed albatrosses.

Observers began providing information on seabird avoidance measures being used by hook-and-line vessels in 1997. The information collection was expanded in early 1999 to incorporate more detailed information about the frequency of measures used during a fishing trip and specific characteristics of different avoidance measures. For example, use of line-weighting regimes (number and size of weights and weight spacing on the groundline), construction and deployment characteristics of towed streamer lines and buoy bags, and the purpose of offal discharge to distract seabirds from baited hooks. Special projects are also being considered that would collect this seabird and gear interaction data on a haul-by-haul, rather than trip basis. Collecting more detailed and specific data will allow for a better analysis of how well avoidance measures reduce seabird incidental catch rates. Beginning in 2000, observers will record the type of seabird avoidance measure being used on vessels fishing with hook-and-line gear on a haul-by-haul basis. This will allow for a more detailed analysis of seabird incidental catch estimates based on the type of avoidance measure being used. This is expected to give some indication of the effectiveness of the avoidance measure.

The duties of fisheries observers in Alaska groundfish fisheries include (in order of priority) recording incidental take of short-tailed albatross and marine mammals, recording fishing effort and catch information, sampling for species composition, documenting compliance problems, collecting biological data on prohibited species, collecting sexed length frequencies and otoliths from the appropriate predominant species, logging sightings of species of interest seabirds and marine mammals, and completing any assigned special projects. For hook-and-line gear, NMFS observers are instructed to observe the line as it comes out of the water and to tally every single animal (target fish, fish bycatch, seabird species, etc.) that comes up on that line (for sampled hauls). This tally includes all animals that fall off the hook and are not physically hauled onboard. Observers are instructed to make the best possible identification of these animals, to species or species group, and to estimate their weight (S. Fitzgerald, NMFS, North Pacific Groundfish Observer Program – personal communication).

Recent studies evaluating seabird mortality in the Japanese tuna longline fishery near Australia suggest that more specialized observers may be required to collect more accurate and reliable information on bird catch rates (Gales et al. 1998, Brothers et al. 1998a). Observers on Japanese tuna longline vessels in the Australian Fishing Zone were asked to record details of passive observations, that is, watch the actual hauling of the longline while not distracted by the additional routine fish sampling tasks. The purpose was for the observer

to gain an overall impression of the operation and to assess the number of seabird discards (i.e., birds hooked but not hauled aboard). Seabird incidental catch rates were higher for these passive observations than for hauls in which the observers were also responsible for fish sampling tasks. Gales et al. (1998) suggest that more accurate and reliable information on bird catch rates could be attained by (1) spending more time watching the set to record numbers of birds hooked, (2) spending more time watching for discards to get a more accurate measure of the catch rate, and (3) collecting comprehensive observations on use of mitigation measures. Based on this description of observer activities in the tuna longline fisheries, NMFS observers in Alaska hook-and-line fisheries are engaged in passive observations. They are not performing other fish sampling duties while observing the haul and tallying hooked species (S. Fitzgerald, NMFS, North Pacific Groundfish Observer Program – personal communication).

Incidental Catch Estimation Procedures

A report using 1993–1997 data from the longline fishery describes seabird incidental catch estimation methods and procedures developed by USFWS, in consultation with NMFS (Stehn et al. 2000). Similar methods and procedures were developed by NMFS and used to calculate preliminary estimates using 1993–1999 data for all groundfish fisheries (M. Perez, NMFS, Alaska Fisheries Science Center – personal communication). Standard statistical procedures for estimating a population total from a sample were used. NMFS calculated rates and estimates for all gears, statistical fishing areas, regions (BSAI or GOA), vessel types (processors, motherships, and catcher-only vessels), time periods (annual or each of 13 four-week periods in a year) for each year from 1993 to 1999, and seabird species or species groups. Eleven groups of seabirds were chosen for analysis: short-tailed albatross, black-footed albatross, Laysan's albatross, unidentified albatross, fulmars, gulls, shearwaters, unidentified tubenoses (procellariids), alcids, other bird species, and unidentified seabirds (those not identified to one of the other ten groups). Preliminary incidental catch estimates were based on the number of seabirds by species in samples from observed hauls and the total commercial fish catch as estimated by the NMFS blend program.

The NMFS method utilized two measures of fishing effort: total tons of groundfish catch per haul or set (all gears), and the number of hooks or pots per set for both the longline and pot fisheries, respectively. The NMFS Observer Program NORPAC database records the weight of the catch by species in the species composition samples and the estimated weight of the entire catch (all species combined) in the whole haul or set. NORPAC also records the number of hooks or pots in the sample and the estimated number of total hooks or pots in the whole set. The number of observed birds in a species composition sample per effort (tons or hooks or pots) of that sample was used to extrapolate the number of seabirds to the whole haul or set, and similarly upwards to the whole fishery, including the unobserved effort. The unobserved weight of fish was calculated by subtracting the known weight of sampled fish on observed hauls from the estimated total weight of fish (all hauls).

The estimated total number of birds caught was the sum of observed birds in the catch and the estimated unobserved birds. For each species or species group, the number of unobserved birds was estimated by multiplying the ratio of the number of observed birds of that species or species group caught per weight of sampled groundfish from observed hauls times the total estimated weight of groundfish caught in unobserved hauls. Both the catch rate of birds (number of birds per weight of fish, or birds per 1,000 hooks) and the catch rate of fish (total weight of all fish species per hook/pot/net) were assumed to be equal for observed and unobserved hauls of the same gear, area, and time period. These assumptions may not hold, not necessarily because the presence of the observer may change the fishing practices of the skipper or crew, but rather because, for some other operational reason, the smaller (unobserved) vessels may have different catch rates than the large or mid-sized vessels. The constant catch rates for birds and/or fish among vessel size categories

are untested and critical assumptions. If different catch rates do exist for different vessel size categories, then the average area catch rates and the estimates of the total sea bird incidental catch number may be overestimated or underestimated.

At the February 1999 North Pacific Fishery Management Council's meeting, the Council's Science and Statistical Committee stated in its minutes that "... Because incidental catch is so small, estimation of the total take of short-tailed albatross is problematic. Uncertainty exists on how the known take of albatross should be expanded to the unobserved portion of the fishery." NMFS and USFWS recognize that this uncertainty exists. Until 1995, a reported take of a short-tailed albatross had not occurred within the observer sample and subsequently, the estimation of short-tailed albatross take in the longline fisheries was even more uncertain. As previously noted, the number of unobserved birds is calculated by multiplying the ratio of the number of birds caught per weight of fish (or 1,000 hooks) sampled from observed hauls by the total estimated weight of fish (or 1,000 hooks) in unobserved hauls. This same procedure was used for all seabird species, including the short-tailed albatross, that were observed in the longline sets sampled by observers. If the sets sampled by observers are not representative of all sets in the longline fishery, a substantial bias could exist in the ratio of the number of birds caught per weight of groundfish caught or 1,000 hooks of line set. In the NMFS preliminary analysis of 1993–1999 observer data, only three of the albatross taken were identified as a short-tailed albatross (and all from the BSAI region). Of the albatross taken, not all were identified. This analysis of 1993–1999 data resulted in an average estimate of two short-tailed albatrosses being taken annually in the BSAI groundfish hook-and-line fishery and zero short-tailed albatross being estimated taken annually in the GOA groundfish hook-and-line fishery. The incidental take limit established in the USFWS biological opinions on the effects of the hook-and-line fisheries on the short-tailed albatross is based on the actual reported takes and not on extrapolated estimated takes.

NMFS preliminary annual estimates of incidental catch rates and incidental catch numbers of seabirds taken in longline gear for 1993 through 1999 are in Tables 3.5-5 and 3.5-6, respectively. NMFS preliminary estimates of annual incidental catch numbers of seabirds taken in trawl and pot gear are in Tables 3.5-7 and 3.5-8, respectively. Current annual estimates for incidental catch in longline gear is discussed further in Section 3.5.4.1. Based on estimates of seabirds observed taken in groundfish fisheries from 1989 to 1993, 85 percent of the total seabird incidental catch was caught in the BSAI, and 15 percent in the GOA. Longline gear accounted for 90 percent of the total seabird incidental catch, trawls for 9 percent, and pots 1 percent (Wohl et al. 1995). NMFS analysis of 1993–1999 observer data indicates similar patterns as those seen in the 1989–1993 data (Figure 3.5-3). Longline gear accounted for 88.1 percent of the total average annual seabird incidental catch, trawl gear for 11.5 percent, and pot gear for less than 1 percent. Based on estimates of seabirds observed taken in groundfish longline fisheries from 1993 to 1999, 86 percent of the longline seabird incidental catch was caught in the BSAI, and 14 percent in the GOA (Table 3.5-6).

The risk to seabirds of getting caught in fishing gear varies with bird species and gear type. Other factors that influence risk include season and location of fishing. Occurrence and density of seabird species at sea vary greatly at different places and times, according to habits of the birds, breeding activities, migration, and habitats, abundance, and movements of forage species.

3.5.4.1 Incidental Catch on Longlines

Longlines catch surface-feeding seabirds that consume invertebrate prey which resemble bait. During setting of the line, seabirds are hooked as they attempt to capture the bait. Birds that habitually scavenge floating material from the sea surface are also susceptible to being hooked on longlines (Brothers 1991, Alexander et al. 1997, Brothers et al. 1999). Recent studies have implicated longline fishing in population declines of albatross species. Longline fishing is considered the most recent and potentially most serious global threat faced by albatrosses and other procellariiformes (Brothers et al. 1999a). Seabird mortality in Alaska longline

fisheries represents only a portion of the fishing mortality that occurs, particularly with albatrosses. Mortality of black-footed and Laysan's albatrosses occurs in both Alaskan and Hawaiian longline fisheries and may be assumed to occur in other North Pacific longline fisheries conducted by Japan, Taiwan, Korea, Russia, and China (Brothers et al. 1999b). USFWS has not analyzed the potential impacts of the seabird incidental catch in the Alaska longline fisheries on other seabird species populations.

Preliminary estimates of the annual seabird incidental catch for the Alaska groundfish fisheries, based on 1993–1999 data, indicate that approximately 17,000 seabirds are taken annually in the combined BSAI and GOA groundfish fisheries (14,600 in the BSAI; 2,300 in the GOA) at average annual rates of 0.10 and 0.06 birds per 1,000 hooks in the BSAI and GOA, respectively (Tables 3.5-5 and 3.5-6).

Of the estimated 14,600 seabirds that are incidentally caught in the BSAI, the species composition is 60 percent fulmars, 17 percent gull species, 12 percent unidentified seabirds, 5 percent albatross species, 4 percent shearwater species, and 2 percent all other species (Figure 3.5-4). Of the estimated 2,300 seabirds that are incidentally caught in the GOA, the species composition is 47 percent fulmars, 37 percent albatrosses, 6 percent gull species, 6 percent unidentified seabirds, 3 percent shearwater species, and less than 1 percent all other species (Figure 3.5-5). Five endangered short-tailed albatrosses were reported caught in the longline fishery since reliable observer reports began in 1990: two in 1995, one in 1996, and two in 1998, all in the BSAI (Table 2.9-3). Both birds caught in 1995 were in the Unimak Pass vicinity and were taken outside the observers' statistical samples; the bird caught in 1996 was near the Pribilof Islands in an observer's sample; the two short-tails taken in 1998 were in observers' samples.

It is difficult at this time to make valid comparisons of bird incidental catch rates between regions (Table 3.5-5). It is not possible to discern whether the differences between the BSAI and GOA estimated incidental catch rates are due to vastly different levels of fishing effort in each region, different vessel types used in each region (small catcher vessel in GOA and large catcher/processors in the BSAI), different distribution and abundance of birds, and so on. An analysis of covariance would allow for a valid statistical comparison of regional incidental catch rates.

Regulatory Measures

NMFS required hook-and-line vessels fishing for groundfish in the BSAI and GOA and federally permitted hook-and-line vessels fishing for groundfish in Alaskan waters adjacent to the BSAI and GOA, to employ specified seabird avoidance measures to reduce seabird incidental catch and incidental seabird mortality in 1997 (62 FR 23176, April 29, 1997). Measures were necessary to mitigate hook-and-line fishery interactions with the short-tailed albatross and other seabird species. Prior to 1997, measures were not required, but anecdotal information suggests that some vessel operators may have used mitigation measures voluntarily. NMFS required seabird avoidance measures to be used by vessels fishing for Pacific halibut in U.S. Exclusive Economic Zone (EEZ) waters off Alaska the following year (63 FR 11161, March 6, 1998). See the proposed rules as well as environmental assessment, regulatory impact review, and final regulatory flexibility analysis prepared for these rulemakings for further discussion of the measures and the development of the regulations (62 FR 10016, March 5, 1997; 62 FR 65635, December 15, 1997; NMFS 1997a, 1998c).

By regulation, all vessel operators using hook-and-line gear to fish for groundfish and Pacific halibut must conduct fishing operations as follows:

1. Use baited hooks that sink as soon as they are put in the water.
2. Discharge offal in a manner that distracts seabirds from baited hooks (if discharged at all during the setting or hauling of gear).

Table 3.5-5 Preliminary Annual Estimates, by Area, of Total Numbers and Bycatch Rates of Seabirds Taken in Longline Fisheries

Year	Effort (No. of Hooks in 1,000s)	No. of Birds	Bycatch Rate No. of Birds per 1,000 Hooks	Percent of Hooks Observed
Bering Sea and Aleutian Islands				
1993	135,581	8,704	0.06	22.3
1994	134,783	10,985	0.08	24.6
1995	141,430	19,892	0.14	24.3
1996	141,540	8,404	0.06	23.8
1997	176,409	18,208	0.10	22.6
1998	175,357	24,871	0.14	23.5
1999	156,087	13,087	0.08	25.2
Average Annual Estimates				
1993–1996	134,095	11,707	0.09	24.5
1997–1999	169,285	18,642	0.11	23.7
1993–1999	148,455	14,580	0.10	24.2
Gulf of Alaska				
1993	56,291	3,102	0.06	10.3
1994	49,452	2,571	0.05	4.9
1995	42,156	2,927	0.07	12.8
1996	33,134	2,321	0.07	10.8
1997	28,000	741	0.03	10.0
1998	29,339	2,270	0.08	8.1
1999	31,894	1,846	0.06	8.6
Average Annual Estimates				
1993–1996	45,258	2,818	0.06	9.5
1993–1999	29,744	2,287	0.06	9.3
1997–1999	38,609	1,566	0.05	8.9

Source: NMFS

Table 3.5-6 Preliminary Estimated Total Incidental Catch of Seabirds by Species or Species Groups^a in Bering Sea and Aleutian Islands and Gulf of Alaska Longline Fisheries, 1993–1999

Year	Actual Number Taken ^b	STAL	BFAL	LAAL	NFUL	Gull	SHWR	Unidentified Tubenoses	Alcid	Other	Unidentified ALB	Unidentified Seabird	Total
Bering Sea and Aleutian Islands													
1993	1,942	0	16	639	4,262	854	81	0	16	4	272	1,753	7,897
1994	2,700	0	28	317	5,130	1,684	659	374	4	4	81	2,701	10,985
1995	4,832	0	74	428	10,086	3,940	338	342	4	193	78	4,409	19,892
1996	2,002	4	21	248	5,432	1,507	567	13	38	55	63	458	8,404
1997	4,123	0	9	353	13,898	2,694	305	62	0	124	13	751	18,208
1998	5,851	9	9	1,492	15,587	4,616	1,169	17	55	94	4	1,819	24,871
1999	3,293	0	16	616	8,310	2,194	620	413	4	79	0	835	13,087
Average Annual Estimate													
1993-1996		1	35	406	6,175	1,979	407	182	15	63	123	2,321	11,707
1997-1999		3	11	823	12,513	3,159	703	171	20	98	6	1,135	18,642
1993-1999		2	25	580	8,814	2,468	530	177	17	78	74	1,817	14,582
Gulf of Alaska													
1993	318	0	78	371	2,009	117	146	0	0	10	10	361	3,102
1994	126	0	41	918	1,265	41	102	0	0	0	41	163	2,571
1995	374	0	454	172	931	196	70	0	0	23	759	321	2,927
1996	250	0	984	371	863	56	19	0	0	0	0	28	2,321
1997	74	0	120	50	461	70	20	0	0	0	0	20	741
1998	184	0	308	247	1,542	123	37	0	0	0	12	0	2,269
1999	159	0	267	499	534	395	93	0	0	12	0	46	1,846
Average Annual Estimate													
1993- 1996		0	459	383	1,267	119	82	0	0	11	264	235	2,820
1997-1999		0	225	255	815	192	49	0	0	4	4	23	1,567
1993-1999		0	360	328	1,073	148	68	0	0	8	156	146	2,287

Notes: ^aSpecies or species group codes.

^bActual number taken is the total number of seabirds recorded dead in the observed hauls.

STAL – Short-tailed albatross

LAAL – Laysan's albatross

BFAL – Black-footed albatross

NFUL – Northern fulmar

Gull – Unidentified gulls (herring gulls, glaucous gulls, glaucous-winged gulls)

SHWR – Unidentified shearwaters (unidentified dark shearwaters, sooty shearwaters, short-tailed shearwaters)

Unidentified Tubenose – Unidentified procellariiformes (albatrosses, shearwaters, petrels)

Alcid – Unidentified alcids (guillemots, murre, puffins, murrelets, auklets)

Other – Miscellaneous birds (could include loons, grebes, storm-petrels, cormorants, waterfowl, eiders, shorebirds, phalaropes, jaeger/skuas, red-legged kittiwakes, black-legged kittiwakes, terns)

Unidentified ALB – Unidentified albatrosses (could include short-tailed albatrosses, Laysan's albatrosses, black-footed albatrosses)

Source: NMFS

Table 3.5-7 Preliminary Estimated Total Incidental Catch of Seabirds by Species or Species Groups^a in the Combined Bering Sea and Aleutian Islands and Gulf of Alaska Trawl Fisheries, 1993–1999

Year	Actual Number Taken ^b	STAL	BFAL	LAAL	NFUL	Gull	SHWR	Unidentified Tubenoses	Alcid	Other	Unidentified ALB	Unidentified Seabird	Total
1993	25	0	0	0	0	0	552	10	204	0	291	179	1,236
1994	45	0	0	0	166	12	170	0	0	0	0	12	360
1995	21	0	0	0	64	0	85	0	64	0	163	443	819
1996	20	0	0	0	50	12	8	19	8	12	0	770	879
1997	55	0	0	6	113	0	521	0	192	0	0	1,171	2,003
1998	45	0	0	854	794	3,620	115	5	474	5	0	30	5,897
1999	154	0	0	37	2,226	0	442	0	3,478	18	0	46	6,247
Average Annual Estimate													
1993–1996		0	0	0	74	6	179	7	61	3	104	367	801
1997–1999		0	0	305	1,124	1,229	358	2	1,500	8	0	378	4,904
1993–1999		0	0	113	462	459	244	5	594	5	65	368	2,315

Notes: ^aSee the species and species groups footnoted in Table 3.5-6.

^bActual number taken is the total number of seabirds recorded dead in the observed hauls.

Table 3.5-8 Preliminary Estimated Total Incidental Catch of Seabirds by Species or Species Groups^a in the Combined Bering Sea and Aleutian Islands and Gulf of Alaska Pot Fisheries, 1993–1999

Year	Actual Number Taken ^b	STAL	BFAL	LAAL	NFUL	Gull	SHWR	Unidentified Tubenoses	Alcid	Other	Unidentified ALB	Unidentified Seabird	Total
1993	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	6	0	0	0	15	8	8	0	15	0	0	0	46
1996	9	0	0	0	49	0	0	0	0	7	0	7	63
1997	4	0	0	0	26	0	0	0	9	0	0	0	35
1998	2	0	0	0	10	10	0	0	0	0	0	0	20
1999	47	0	0	0	378	0	9	46	0	0	0	0	433
Average Annual Estimate													
1993–1996		0	0	0	16	2	2	0	4	2	0	2	28
1997–1999		0	0	0	137	3	3	15	3	0	0	0	161
1993–1999		0	0	0	61	2	2	6	3	1	0	1	76

Notes: ^aSee the species and species groups footnoted in Table 3.5-6.

^bActual number taken is the total number of seabirds recorded dead in the observed hauls.

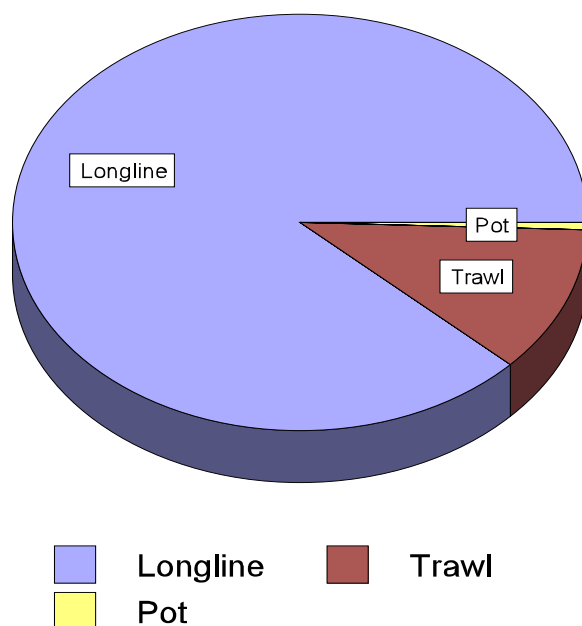


Figure 3.5-3 Average annual number of seabirds taken by gear types in both the Bering Sea and Aleutian Islands and Gulf of Alaska, 1993–1999. Source: NMFS

Bird Bycatch Species Composition in BSAI

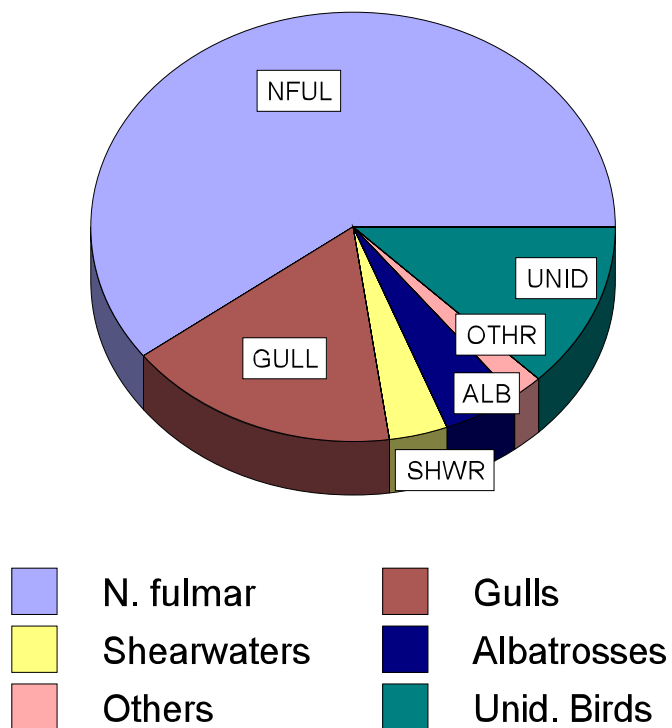


Figure 3.5-4 Relative species composition of bird incidental catch in the longline fisheries in the Bering Sea and Aleutian Islands. Average annual estimates, 1993–1999. Source: NMFS

Bird Bycatch Species Composition in GOA

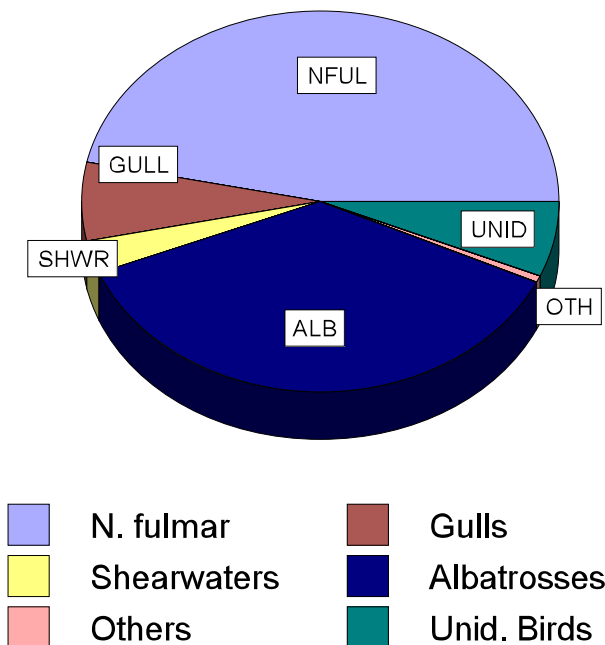


Figure 3.5-5 Relative species composition of bird bycatch in the longline fisheries in the Gulf of Alaska. Average annual estimates, 1993–1999. Source: NMFS

3. Make every reasonable effort to ensure that birds brought on board alive are released alive. In addition, all applicable hook-and-line vessels at or more than 26-ft length overall, must employ *one or more* of the next four measures.
4. Set gear at night (during hours specified in regulation).
5. Tow a streamer line or lines during deployment of gear to prevent birds from taking hooks.
6. Tow a buoy, board, stick, or other device during deployment of gear at a distance appropriate to prevent birds from taking hooks.
7. Deploy hooks underwater through a lining tube at a depth sufficient to prevent birds from settling on hooks during the deployment of gear.

Alaskan fishermen currently are provided some flexibility in choice of options in that they can select the most appropriate and practicable methods for their vessel size, fishery, and fishing operations and conditions. A similar approach allowing the choice of options will be used in Australia's Threat Abatement Plan for the incidental catch of seabirds during oceanic longline fishing operations (Environment Australia 1998).

NMFS completed and submitted to USFWS a *Test Plan to Evaluate Effectiveness of Seabird Avoidance Measures Required in Alaska's Hook-and-Line Groundfish and Halibut Fisheries* (test plan; NMFS 1998d).

The test plan focuses on three key components to evaluate the effectiveness of seabird avoidance measures:

1. experimental testing of avoidance measures,
2. collection of information on avoidance measures by observers on commercial vessels, and
3. solicitation and gathering of information from fishermen on the effectiveness of seabird avoidance measures.

The Washington Sea Grant Program began experimental research studies in 1999 to test the effectiveness of selected seabird incidental catch deterrent measures in the individual fishing quota (IFQ) halibut and sablefish fishery and in the BSAI Pacific cod freezer-longliner fishery. Paired streamer lines and weighted gear are the two deterrent measures being tested against a control in the IFQ fishery. Line shooters, lining tubes, and weighted gear are the three deterrent measures being tested against a control in the BSAI Pacific cod fishery. This experimental study will continue for its second season in 2000. Results should be available in early 2001. When final results are available and have been analyzed, NMFS anticipates that Washington Sea Grant Program may recommend to NMFS and the Council various suggestions for regulatory changes to improve the effectiveness of the seabird avoidance regulations. As noted previously, the observer data that are collected on hook-and-line vessels have been amended to more directly reflect on the effectiveness of measures used. NMFS continues to communicate with fishermen to address the effectiveness of avoidance measures they are using. A seminar on this topic was held at the 1997 Fish Expo in Seattle, Washington (jointly sponsored with North Pacific Longline Association and USFWS) and information was solicited at the 1998 Fish Expo.

Enforcement of Seabird Avoidance Regulations

The U.S. Coast Guard assumed an aggressive and proactive policy of educating commercial hook-and-line fishermen in the months prior to regulations being effective. At-sea enforcement has continued this policy in checking for compliance with regulations during at-sea boardings. Reports of these compliance checks are made in the Coast Guard's report to the Council at each meeting. NMFS Enforcement currently is investigating several cases involving alleged violations of seabird avoidance regulations and other seabird-related issues (T. DuBois, NMFS Enforcement – personal communication).

3.5.4.2 Incidental Catch in Trawls

Trawls primarily catch seabirds that dive for prey. This probably occurs as the trawl is being retrieved, rather than while it is actively fishing. A few birds may also be caught as they attempt to scavenge fish or detritus at the surface during retrieval. The species composition of seabird incidental catch in observed trawl hauls is currently available for 1993 through 1999. The principal bird species reported in trawl hauls were alcids, northern fulmars, and gulls. Small numbers of other species were also caught (Table 3.5-7). NMFS's analysis of 1993–1999 observer data indicates that trawl gear accounted for 11.5 percent of the total average annual seabird incidental catch in the BSAI and GOA groundfish fisheries combined (Figure 3.5-3).

There is evidence that some forms of trawling may make fish vulnerable to diving birds by disturbing or injuring the fish. Black guillemots (Ewins 1987) and great cormorants (*Phalacrocorax carbo sinensis*) in the North Atlantic Ocean (Camphuysen 1999) are two species that may have learned to take advantage of such disruptions.

Onboard observations of birds (including Laysan's albatross) colliding with the trawl transducer wires (sometimes called third wire) have been made. These wires are typically deployed midship from a davit on midwater trawl vessels fishing for pollock and carry the transducer net sounder cable down to the head of the

trawl net. Any birds killed by such collisions would most likely not be recorded in observers' samplings of the trawl haul in that it is unlikely that such dead birds would make their way into the trawl net. This potential interaction was noted in the November 4, 1998, letter from the NMFS Alaska Regional Administrator to the USFWS Field Supervisor of the Office of Ecological Services, that initiated the Section 7 consultation for the 1999–2000 groundfish longline fisheries. NMFS determined that the groundfish trawl vessels that deploy such a cable “may affect” short-tailed albatross. Although collisions with short-tailed albatrosses have not been observed or reported, NMFS and USFWS staff felt the potential was there, given that the closely related Laysan's albatross has been observed colliding with the wires. The December 2, 1998, response from USFWS noted that this “may affect” determination constituted an active informal Section 7 consultation with no statutory deadlines. NMFS is initiating efforts to research the issue to determine the extent of use of trawl third wires in the trawl fleet and specifics of the bird/vessel interactions. Solutions may be as simple as hanging streamers from the third wire (G. Balogh, USFWS, Anchorage – personal communication).

3.5.4.3 Vessel Strikes

Although observers have reported birds in flight striking vessels, bird-strike data have not yet been statistically analyzed. Some birds that strike vessels fly away without injury, but others are injured or killed. Bird strikes are probably most numerous during the night; birds are especially prone to strike vessels during storms or foggy conditions when bright deck lights are on, which can cause the bird to be disoriented. The proximity of the vessels to seabird colonies during the breeding season is also a factor (V. Byrd, USFWS – personal communication). Collisions of large numbers of birds occasionally occur, as in the case of approximately 6,000 crested auklets that were attracted to lights and collided with a fishing vessel near Kodiak Island during the winter of 1977, or in the central Aleutians in 1964 when approximately 1,100 crested auklets were attracted to deck lights on a processor and collided with structures on the vessel (Dick and Donaldson 1978). Species that most commonly strike vessels include storm-petrels, auklets, and shearwaters. Albatrosses have been observed striking the vertical cables from which sonar transducers of trawlers are suspended. Little information is available on the problem of transducer cables.

3.5.5 Processing Wastes and Discards

Although the location of breeding sites influences seabird feeding distribution, fisheries also have a strong influence, on a smaller scale, on the distribution of seabirds at sea (Garthe and Huppopp 1994). Fish deheading and processing provide food directly to a few seabird species whose normal foraging behavior includes scavenging on dead material. These species include northern fulmars, large gulls, black-footed albatrosses, and possibly black-legged kittiwakes (Patten and Patten 1982, Furness and Ainley 1984, Gould et al. 1997). Fulmars and albatrosses feed on wastes and discards at sea, whereas gulls feed on the same at sea, near shore, and on land.

Scavenging by gulls can influence population trends in either direction. Scavenged processing wastes and other artificial foods may not be adequate foods for successfully rearing chicks (Murphy et al. 1984, Baird and Gould 1986, Irons et al. 1986, Sanger 1986). On the other hand, abundant scavenging during winter may increase gull populations because survival of immature birds is enhanced (Patten and Patten 1982). Larger gull numbers can reduce local populations of other birds through increased competition for nest sites and predation pressure on their young, although scientists disagree about the magnitude of this problem (Spaans and Blokpoel 1991). Hunt (1972) found that herring gulls, on the coast of Maine that used discarded waste had increased breeding success. Studies on two gull species (lesser black-backed [*L. fuscus*] and yellow-legged [*L. cachinnans*]) in Spain indicate that a dependence on discards from commercial fishing activities may be a limiting factor in the breeding success of these species (Oro et al. 1995, Oro 1996). Garbage may have lower caloric density than the best of the forage fishes, but when good-quality forage fish are scarce, food from discards, offal, and garbage may be important for successful reproduction (G. L. Hunt, Jr., University of

California, Irvine – personal communication). About 30 percent of total food consumed by seabirds in the North Sea is estimated to be discards (including offal) (Tasker and Furness 1996). These foods are, therefore, of direct importance in sustaining populations of some seabirds. Numerous instances are cited showing potential relationships between discards in diets and changes in breeding populations (Garthe et al. 1999). It may be that the poor reproductive success of birds dependent on discards reflects that the discards are being used as a substitute food in the absence of abundant natural prey near the colonies. Use of discards may require longer or more costly foraging trips (G. L. Hunt, Jr., University of California, Irvine – personal communication). Populations of other scavenging species such as northern fulmar may be influenced, to some extent, by artificial food (Furness 1984), but no data are available on these effects in Alaska.

In many areas of the world, fishery discards appear to have benefitted certain seabird species, primarily large aggressive and predatory species (Furness 1999). For example, in the North Sea, populations of great skuas (*Catharacta skua*) and black-backed gulls (*Larus marinus*) have increased due to utilization of fishery discards, and these birds prey on other seabird species. Sudden withdrawal of discards might cause the predatory species to increase pressure on kittiwakes, puffins, and guillemots long before the skuas and gulls decline to previous levels (Furness 1999).

3.5.6 Effects of Vessels on Seabirds

Fishing vessels can affect seabird populations whether or not the vessels are engaged in fishing or processing activities. Many surface-feeding birds are attracted to vessels (Furness 1999), but others, such as marbled murrelets, may be displaced from forage areas by vessel activity (Kuletz 1996). Fishing vessels, like all other types of vessels, can influence seabird habitats. Three potential impacts are oil spills, introductions of rats onto seabird nesting islands, and plastics ingestion.

3.5.6.1 Oil Spills

The threat of oil spills to seabirds is well-known. Many field and laboratory studies have demonstrated the differences in the effects of oil on various groups of birds. The three most important factors affecting sensitivity are behavior, distribution, and reproductive rate (Huguenin et al. 1996). A dramatic accident like the *Exxon Valdez* oil spill may kill hundreds of thousands of seabirds (Piatt et al. 1990, Piatt and Ford 1996). However, much more common are chronic small spills of a few gallons caused by accidents during routine activities such as fuel transfer operations and bilge cleaning. For instance, in Dutch Harbor between November 1997 and June 1998, 13 oil or fuel spills were reported. The largest spill was 47,000 gallons from the *M/V Kuroshima*; the remainder of the spills were 1 to 15 gallons each. In the winter of 1996, the freighter *M/V Citrus* collided with a crab processing vessel off Saint Paul Island, spilling an unknown quantity of bunker oil, which killed over 1,700 birds (Flint et al. 1998). Oil and fuel spills in the North Pacific Ocean have increased during the past two decades (Burger and Fry 1993). Chronic spills may be a greater threat to seabirds than the occasional large spill (Burger and Fry 1993), especially in sheltered areas where both vessels and seabirds assemble in large numbers.

Oil kills birds because it damages the feathers, which are necessary to insulate the bird from cold water, and also because the bird ingests toxic oil fractions as it tries to clean its plumage and suffers damage to various internal organs and its immune system (Burger and Fry 1993). Birds may also be directly exposed to oil through oiling of eggs, ingestion of oiled prey, absorption, and inhalation of oil through the skin or egg (Huguenin et al. 1996). Oiled feathers also affects the bird's buoyancy and ability to dive and fly. Since the insulation value of the feather is reduced, energy demands increase, requiring the birds to feed more when they are least able to do so (Wiens 1995). Direct mortality from exposure to floating slicks can be high, especially during incidents involving persistent oils and when large numbers of birds are concentrated in migration and overwintering areas. For most coastal incidents, diving ducks are at greatest risk because of their preference

for nearshore marine waters (Research Planning Inc. 1988). Seabird reproduction can also be affected by spilled oil through effects to the endocrine system or by directly transferring oil to eggs, which affects hatching success. There can be long-term impacts on reproduction because of irregular cycles in breeding success, nesting abandonment, and mate switching by oiled adults (Fry et al. 1987). Time of the year is also an important factor, with the colder winter months the most vulnerable time. In addition to the direct pathways of exposure listed above, birds may be indirectly affected by oil through habitat loss (e.g., vegetation mortality), habitat degradation, and diminished food populations (Huguenin et al. 1996). All types of oil and fuel are dangerous, and only a few drops of oil are enough, under some situations, to kill a seabird.

The species at most risk are diving seabirds, which spend more time resting on the water than do surface-feeders (King and Sanger 1979). More specifically, alcids are considered to be the most vulnerable to oil of all bird groups, followed by diving ducks. Diving pelagic seabirds (albatrosses, petrels, fulmars, shearwaters, skuas, and jaegers) are moderately sensitive to oil effects given their extreme reliance on open-water marine habitats for feeding and roosting, making them susceptible to incidents in these settings. Gulls and terns are usually oiled in low proportion to the exposed populations because they are readily able to avoid oil (Huguenin et al. 1996). A large oil spill can reduce local populations of vulnerable species for several years. For instance, several diving seabirds were reduced significantly or killed disproportionate to their population by the *Exxon Valdez* oil spill (Piatt and Ford 1996, Carter and Kuletz 1995, Oakley and Kuletz 1996). Murre populations and their breeding success have taken several years to recover (Piatt and Anderson 1996, Roseneau et al. 1998); pigeon guillemot populations still had not recovered nine years later, probably because foraging conditions were inadequate to support an increase in the population (Hayes and Kuletz 1997). Harlequin duck populations in Prince William Sound experienced reduced survival as a result of the *Exxon Valdez* oil spill and the continued effects of the oil spill have likely restricted recovery of harlequin duck populations through at least 1998 (Esler et al. 2000).

3.5.6.2 Introduced Mammalian Predators on Nesting Islands

Seabird colonies on nesting islands are extremely sensitive to introductions of exotic predators. Seabirds nest on inaccessible islands and steep cliffs because these habitats provide protection against predators such as arctic (*Vulpes fulva*) and red (*Alopex lagopus*) foxes and rats (*Rattus norvegicus*). These mammals attack eggs, chicks, and even adult birds. When Vitus Bering first discovered Alaska in 1741, most islands in the Aleutian chain, along the south coast of the Alaska Peninsula, and in the GOA were not inhabited by foxes (Bailey and Kaiser 1993). In contrast, arctic foxes and, on a few nearshore islands, red foxes, were indigenous to the islands in the Bering Sea. Apparently, foxes did not occur on any of the central or western Aleutians. Where foxes have invaded islands that previously had no ground predators, almost all seabirds have experienced breeding failures and population declines. Foxes have been removed from most islands by the USFWS, except where they occur naturally (Bailey 1993).

At present, rats pose the greatest predator threat to seabirds breeding in Alaska. Rats are voracious predators; they may be even more dangerous to seabird nests than foxes, because they can burrow, enter crevices, and climb cliffs with great agility (Jones and Byrd 1979). They can also kill small adult birds (Bailey 1993).

Rats are not native to Alaska, but they have become established on 22 Alaskan islands, including Kodiak Island and various islands in the Aleutian Islands. Rats probably jumped or swam ashore at islands with ports, especially those with docking facilities. Rats are also prone to invade any island on which a vessel is wrecked (Brecht 1977, Jones and Byrd 1979, Bailey 1993). The effects of rat invasions on local seabird populations are not known in Alaska, because no islands have been monitored before and after their arrival. However, for most islands in other parts of the world where rats have invaded, seabird populations have declined or become extinct (Jones and Byrd 1979, Moors et al. 1992, Burger and Gochfeld 1994).

Extermination of rats is difficult and expensive (Moors et al. 1992), and it may be impossible for islands larger than a few hundred acres.

Rats are a major management concern. The USFWS in Alaska has an extensive program to reduce the threat of new rat invasions. Efforts include maintaining networks of poison-bait boxes at ports on rat-free islands such as Saint Paul Island; training local communities to monitor and counteract to rats aboard ships and on land; conducting public outreach programs to encourage operation of rat-free vessels in Alaskan waters; and training emergency-response teams to attack rats when they are found at remote shipwrecks. These efforts are in early stages, however, and the threat of rat invasions from vessels remains very serious. It is not known what proportion of fishing vessels carry rats, nor what proportion of presently rat-free vessels could rid themselves of the rats if re-infested. The threat to seabird populations, therefore, cannot be quantified.

In spite of long-term, severe predation pressure, enough seed populations remain in Alaska to permit the recovery of devastated species on increasing numbers of fox-free islands. Through the Aleutian Islands and the other smaller islands off Alaska, seabird populations have rebounded after the removal of foxes, except where populations of rodents remain (Bailey and Kaiser 1993).

3.5.6.3 Plastics Ingestion

The presence of plastic pollution in marine waters was first recorded from marine birds in the northwestern Atlantic Ocean in 1962, essentially coinciding with the increase in production of plastic resin during the past few decades (Robards et al. 1997). To date, ingestion of plastic pollutants has been recorded in 80 species of marine birds from around the world (Sievert and Sileo 1993). The highest frequencies of plastic ingestion are recorded in procellariiformes and in the parakeet auklet, whereas larids (gulls) and most alcids ingest little or no plastic. Species feeding primarily by surface-seizing or pursuit-diving have the highest frequencies of plastic ingestion. All ingested plastic found has been in the gizzards and, occasionally, proventriculi of the birds examined (Day et al. 1985). Species feeding primarily on crustaceans or cephalopods have the highest frequencies of plastic ingestion; secondary ingestion of plastics via fish appears to be unimportant. Subadult seabirds ingest more pieces of plastic than do adult seabirds (Day et al. 1985) and adult seabirds may pass plastics on to chicks by regurgitation (Robards et al. 1997).

Two classes of plastic are commonly found in seabirds; pellets and fragments. Pellets are the raw product of the plastic industry and most probably enter the marine ecosystem during transportation or via drainage systems. Plastic fragments or “user” plastics are small, weathered pieces of larger manufactured items that are discarded or lost at sea, particularly from fishing boats and marine shipping vessels (Robards et al. 1997). Ocean currents, winds, and the location of disposal influence the abundance and distribution of plastic in the North Pacific Ocean (Auman et al. 1997). The highest incidence of ingested particles in the subarctic North Pacific was in the Aleutian coastal waters. Densities of small plastic particles in the subarctic North Pacific and Bering Sea are 26 to 400 times lower, respectively, than in subtropical waters. Of small oceanic plastic particles found in the central North Pacific, 3.7 percent were pellets and 96.3 percent were user fragments (Robards et al. 1997). In contrast, seabirds in the subarctic North Pacific ingested mostly pellets (76 percent pellets, 22 percent user plastic, 2 percent unrecognizable plastic particles) (Robards et al. 1997). Some of the recognizable plastic objects are consistent with debris originating from dumping as opposed to fishing activities.

Available evidence suggests that plastics are damaging to seabirds when they are consumed in sufficient quantity to obstruct the passage of food or cause stomach ulcers. Other effects may include bioaccumulation of polychlorinated biphenyls, toxic effects of hydrocarbons, diminished feeding stimulus, reduced fat deposition, lowered steroid hormone levels, and delayed reproduction. However, at present, acute effects of plastic ingestion are rarely observed, and chronic effects on body condition are generally equivocal (Robards

et al. 1997). Studies on Midway Island found that ingested plastic probably does not cause significant direct mortality in Laysan's albatross chicks (Auman et al. 1997) or black-footed albatross chicks (Sievert and Sileo 1993), but likely causes physiological stress as a result of satiation and mechanical blockages (Auman et al. 1997) and may affect chick survival when the volume of plastic ingested is high (Sievert and Sileo 1993).

It may not be possible to demonstrate direct cause-and-effect relationships between plastic ingestion and body condition in wild seabirds because of natural variability in the environment and the fact that affected birds may quickly disappear from sampled populations (Robards et al. 1997).